

CKM Phases: $_{-1}/_{-}$

Tom Browder (University of Hawaii)

*Measurements of large
CPV in $b \rightarrow c \bar{c} s$ modes*

Studies in $b \rightarrow c \bar{c} d$ modes

*Search for New Physics:
CPV in $b \rightarrow s$ penguin
modes*

Belle and BaBar results



KM ansatz: CPV is due to a complex phase in the quark mixing matrix:

$$\begin{array}{c}
 \left| \begin{array}{c} d' \\ s' \\ b' \end{array} \right\rangle = \left| \begin{array}{c} V_{ud} \\ V_{cd} \\ V_{td} \end{array} \right\rangle \left| \begin{array}{c} V_{us} \\ V_{cs} \\ V_{ts} \end{array} \right\rangle \left| \begin{array}{c} V_{ub} \\ V_{cb} \\ V_{tb} \end{array} \right\rangle \left| \begin{array}{c} d \\ s \\ b \end{array} \right\rangle
 \end{array}$$

$$\begin{array}{ccccc}
 \left| \begin{array}{c} V_{ud} \\ V_{cd} \\ V_{td} \end{array} \right\rangle & \left| \begin{array}{c} V_{us} \\ V_{cs} \\ V_{ts} \end{array} \right\rangle & \left| \begin{array}{c} V_{ub} \\ V_{cb} \\ V_{tb} \end{array} \right\rangle & \left| \begin{array}{c} 1 \boxed{\theta}^2 / 2 \\ \boxed{\theta} \\ A \boxed{\theta}^3 (1 \boxed{\theta} \boxed{i} \boxed{\theta}) \end{array} \right\rangle & \left| \begin{array}{c} \theta \\ 1 \boxed{\theta}^2 / 2 \\ \boxed{A} \boxed{\theta}^2 \end{array} \right\rangle \\
 = & & = & & = \\
 \left| \begin{array}{c} V_{ud} \\ V_{cd} \\ V_{td} \end{array} \right\rangle & \left| \begin{array}{c} V_{us} \\ V_{cs} \\ V_{ts} \end{array} \right\rangle & \left| \begin{array}{c} V_{ub} \\ V_{cb} \\ V_{tb} \end{array} \right\rangle & \left| \begin{array}{c} 1 \boxed{\theta}^2 / 2 \\ \boxed{\theta} \\ A \boxed{\theta}^3 (1 \boxed{\theta} \boxed{i} \boxed{\theta}) \end{array} \right\rangle & \left| \begin{array}{c} \theta \\ 1 \boxed{\theta}^2 / 2 \\ \boxed{A} \boxed{\theta}^2 \end{array} \right\rangle
 \end{array}$$

The B Physics Program

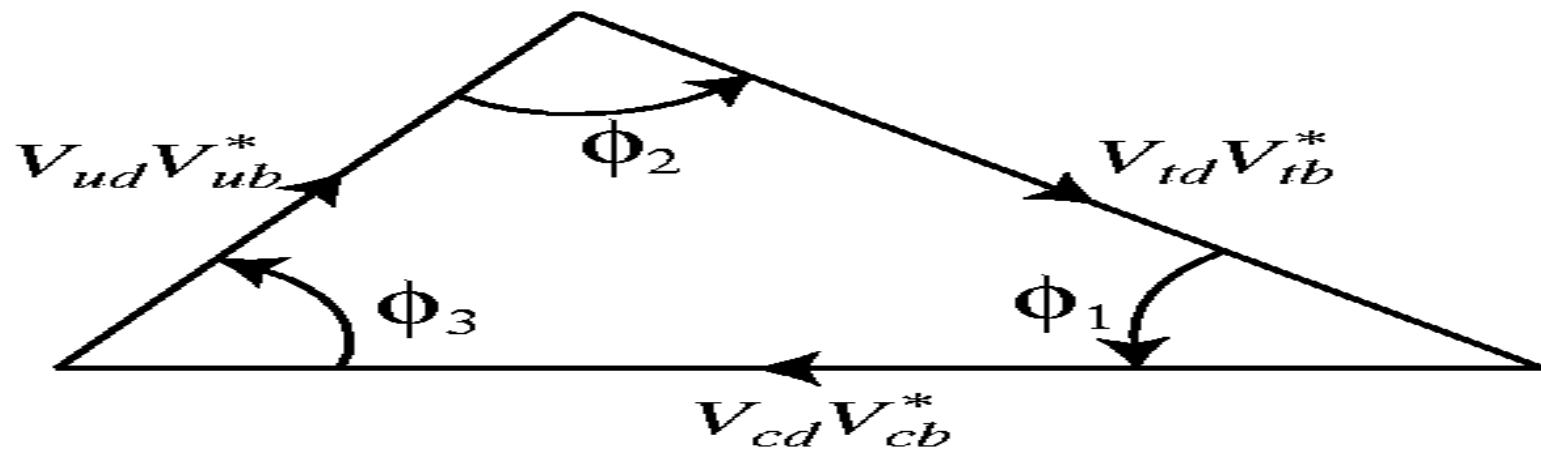
Quark couplings are complex and lead to CP violation. *Is CP violation a result of a single weak phase in the KM matrix ?*

Or is it a signal of new interactions beyond the Standard Model ?

Is there new physics in loop decays ?

Notational Conventions

Three Angles: $(\underline{_}_1, \underline{_}_2, \underline{_}_3)$ or $(_, _, _)$



Birthname: Matsui

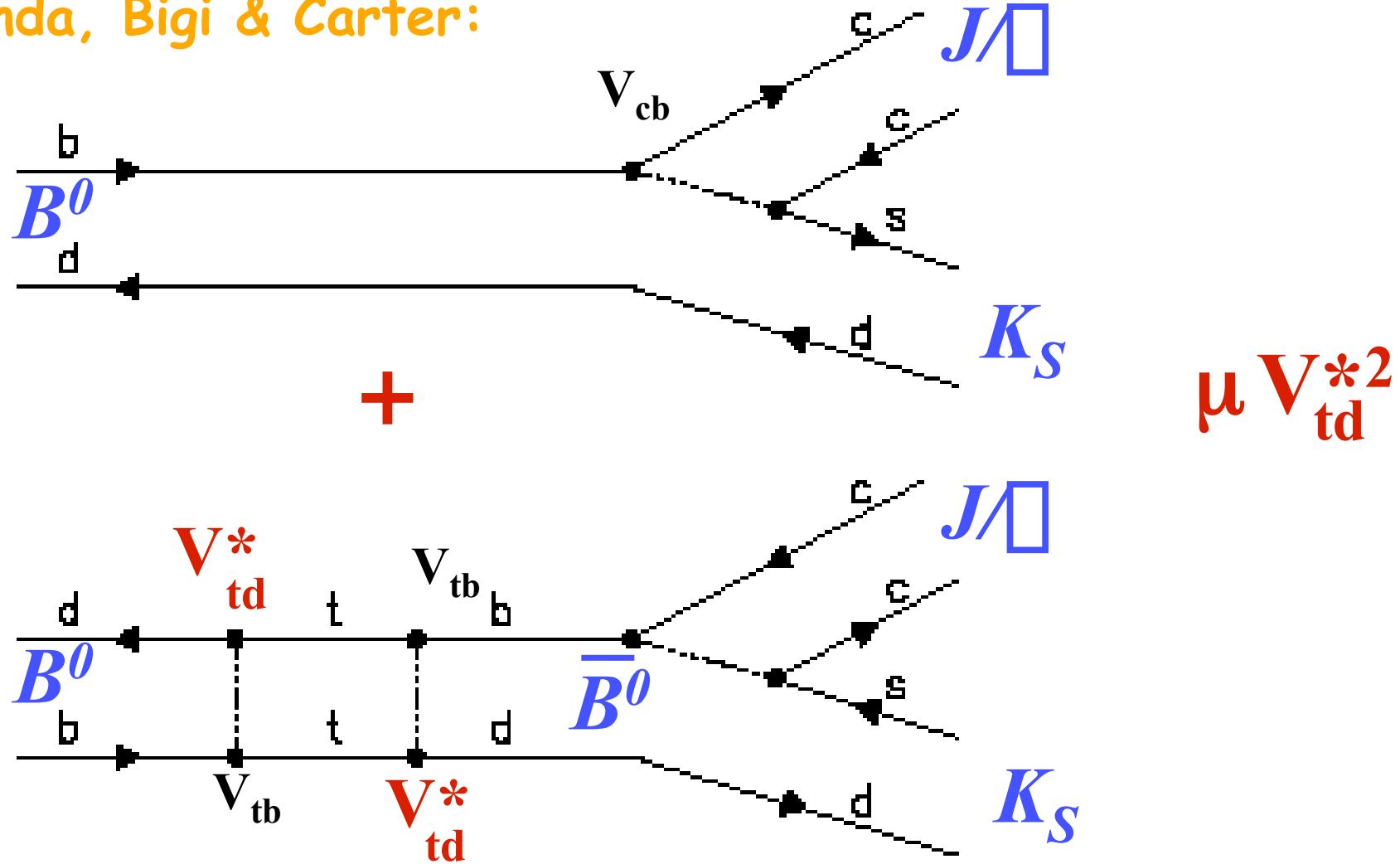
$$\square_1 \\ \square_2 \\ \square_3$$

Nickname: Godzilla

$$\square \\ \square \\ \square$$

$\sin 2\beta_1$ from $B \bar{B} f_{CP} + \bar{B} \bar{B} \bar{f}_{CP}$ interf.

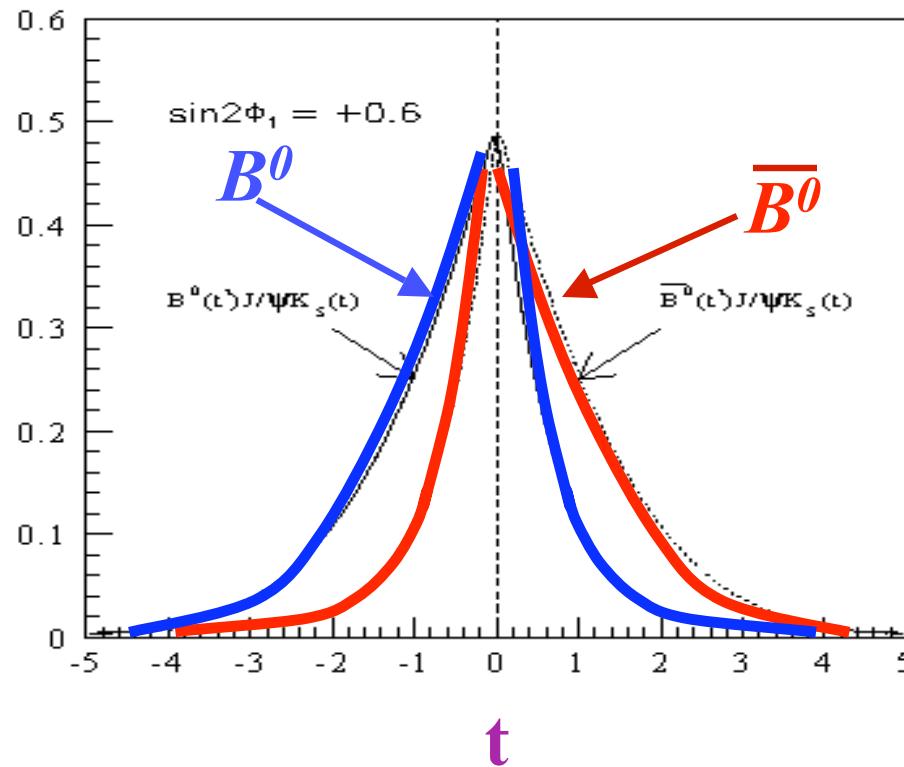
Sanda, Bigi & Carter:



Mixing-induced CPV asymmetry

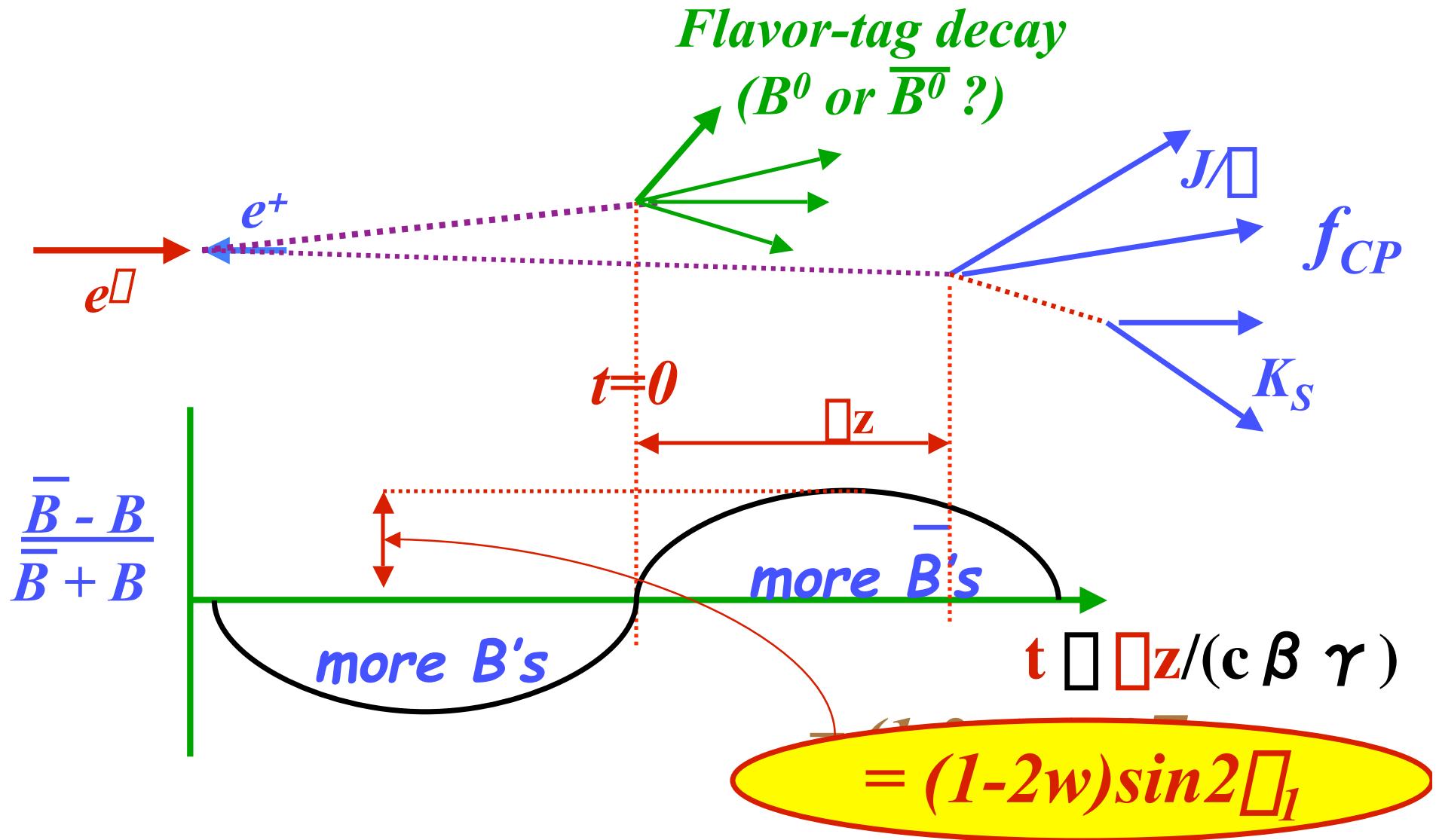
$$A(t) \equiv \frac{\Gamma(\bar{B}_d^0 \rightarrow f_{CP}) - \Gamma(B_d^0 \rightarrow f_{CP})}{\Gamma(\bar{B}_d^0 \rightarrow f_{CP}) + \Gamma(B_d^0 \rightarrow f_{CP})} = -\xi_f \sin 2\phi_1 \sin \Delta m t$$

$\square_f = \pm 1 \text{ for } CP = \pm 1$



a.k.a $2\square$

Principle of the Measurement



If there is *more than one diagram* and additional weak phases, there is the possibility of *direct CPV* and a new term with a $\cos(_m_t)$ time dependence.

$$P(B \rightarrow f_{CP}; t) = \frac{e^{-|t|/B}}{4} [1 + q \cdot \{A \cos(m t) + S \sin(m t)\}]$$

with $q=\pm 1$

$$S = \frac{2 \operatorname{Im} \Gamma}{|\Gamma|^2 + 1}$$

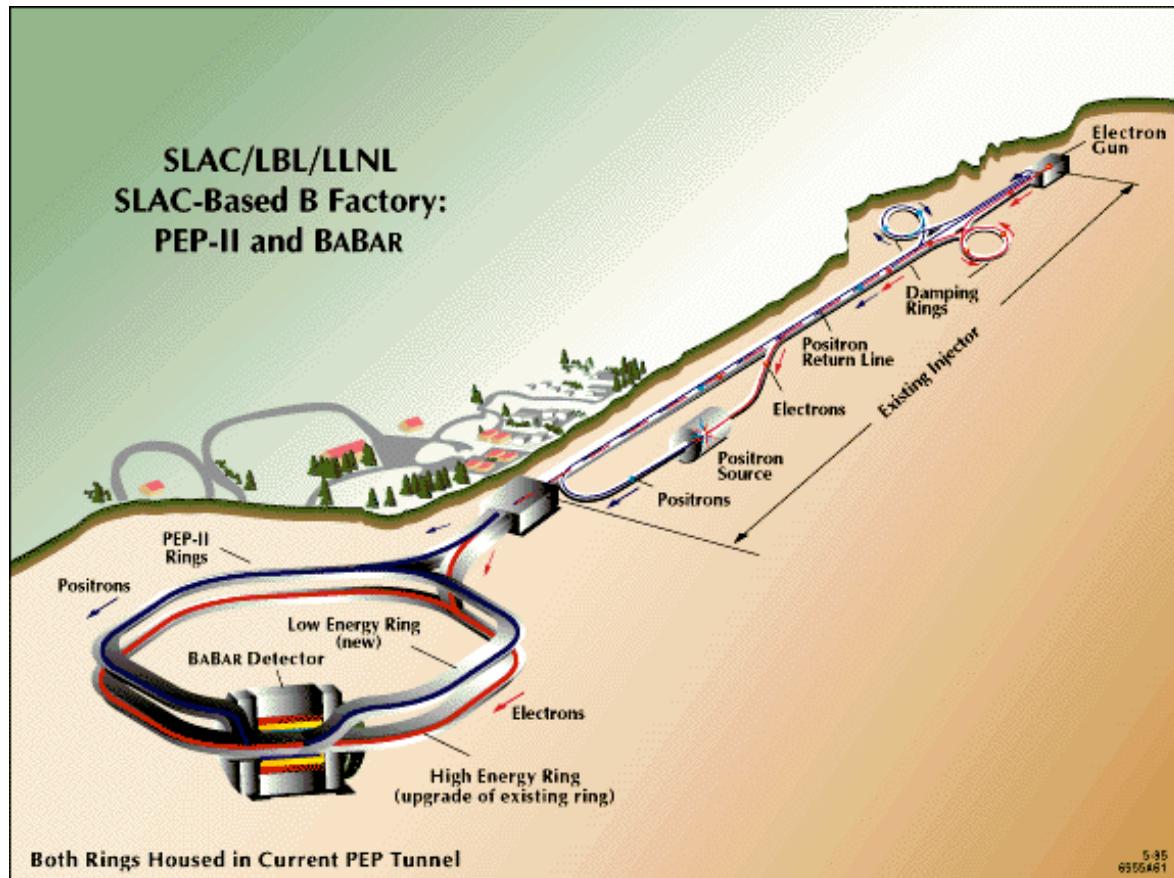
$$A = \frac{|\Gamma|^2 - 1}{|\Gamma|^2 + 1}$$

C(Babar)=-A(Belle)

Requirements for CPV measmts.

- Many B mesons [$Br(B \rightarrow f_{CP}) \sim O(10^{-3})$]
 - 2003: PEP-II → 131 fb⁻¹; KEKB → 158 fb⁻¹, 10% taken below resonance.
- Reconstruct+isolate CP eigenstate decays
 - Kinematic variables for signal +(*cont. bkg suppr+PID*).
- Tag flavor of the other B
 - Hierachial NN (Babar) or Likelihood (Belle) based flavor tagging
- Measure decay-time difference
 - Asymmetric beam energies, high precision vertexing($_z$)
 - Likelihood fit to the Δt distributions

The PEPII Collider (magnetic separation)



$\text{Int}(L dt) = 131 \text{ fb}^{-1}$

On resonance: 113 fb^{-1}

$9 \times 3.0 \text{ GeV}; L = (6.5 \times 10^{33})/\text{cm}^2/\text{sec}$

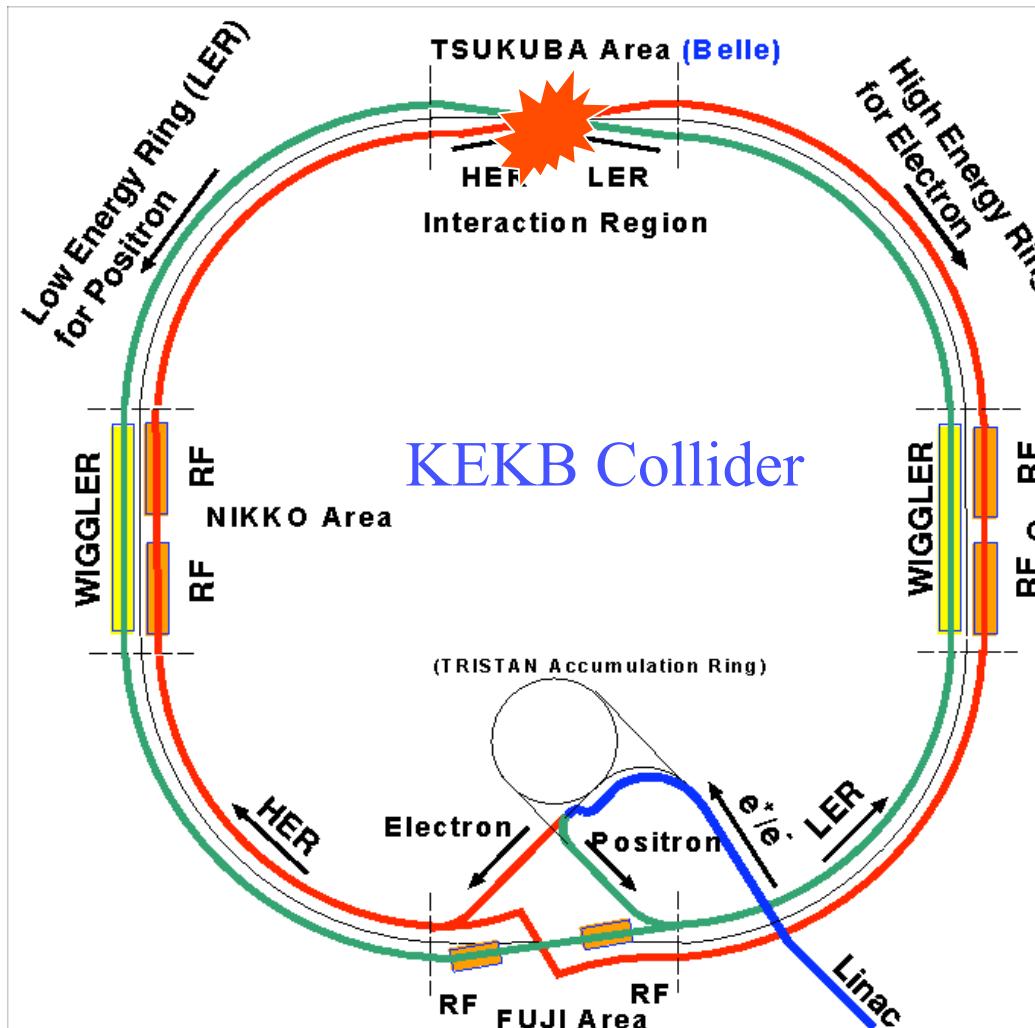
The KEKB Collider (8×3.5 GeV, X angle)

World record:

$$L = (1.0 \times 10^{34})/\text{cm}^2/\text{sec}$$

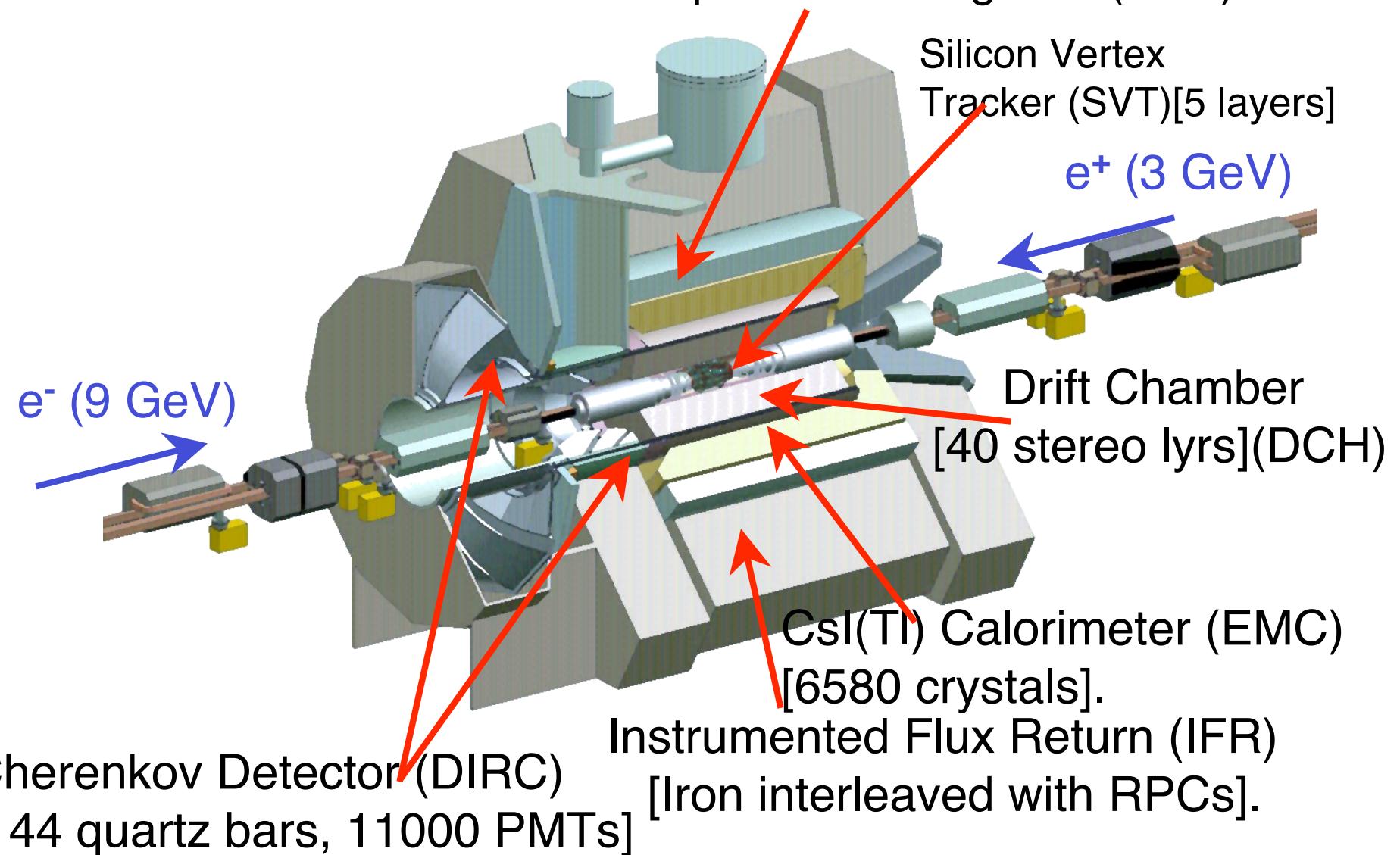
$$\text{Int}(L dt) = 158 \text{ fb}^{-1}$$

On-resonance 140 fb^{-1}

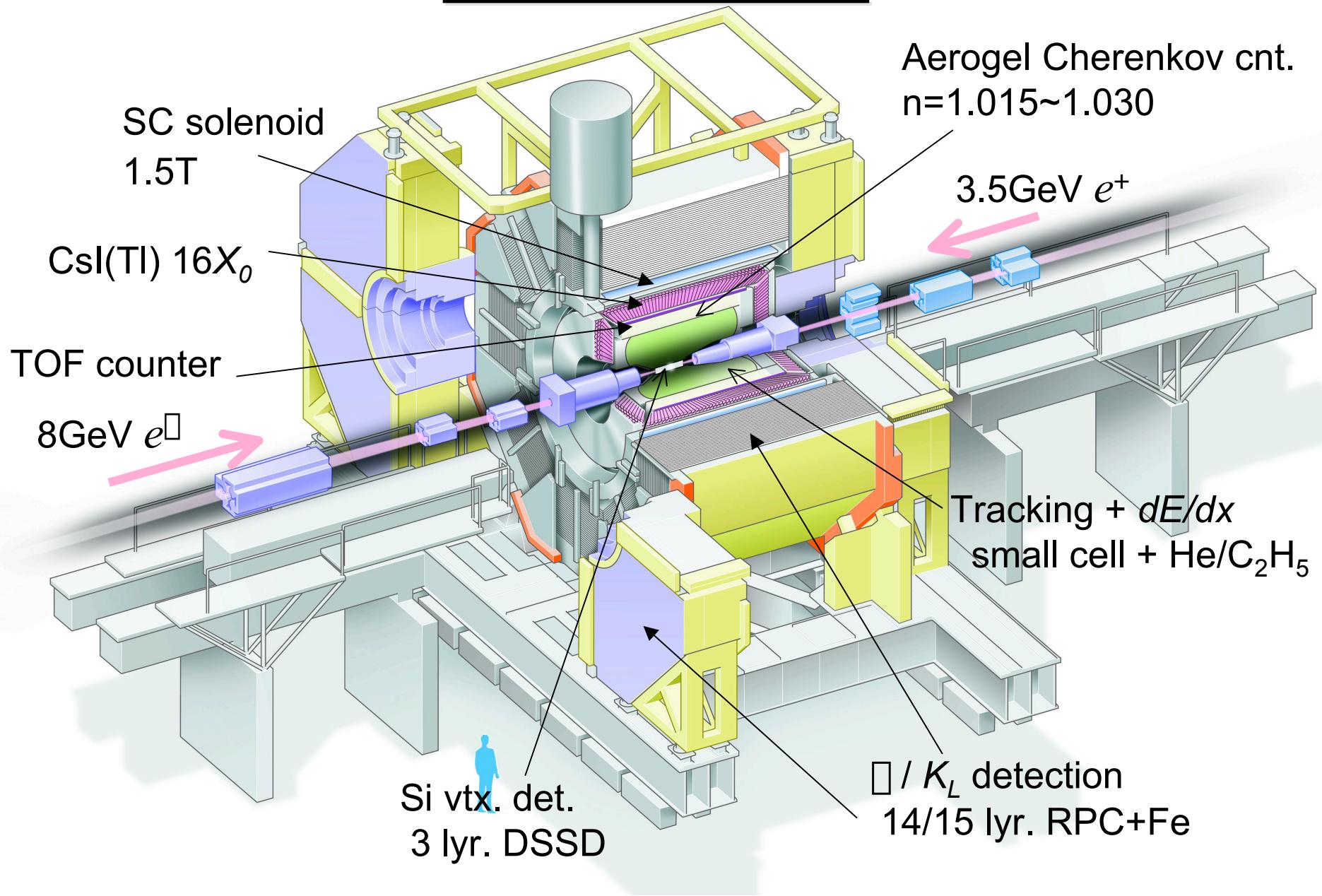


The BaBar Detector

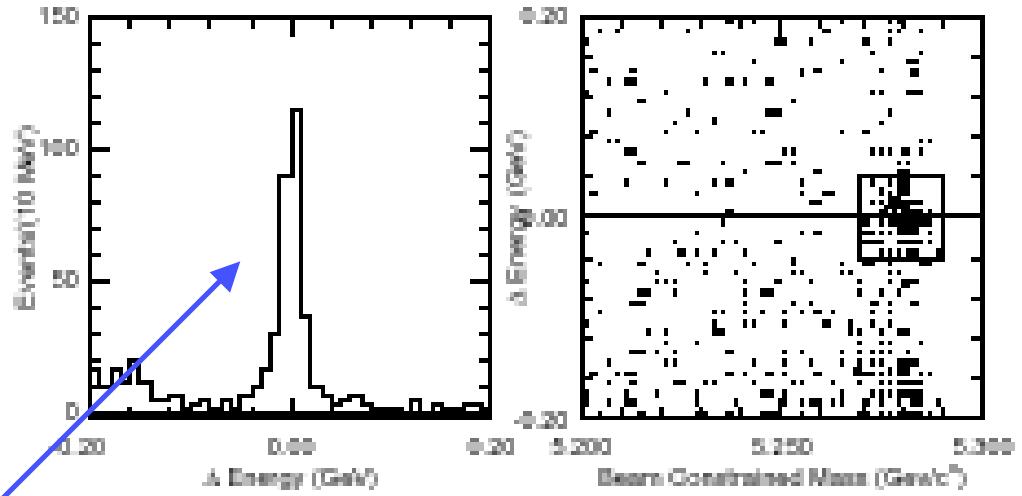
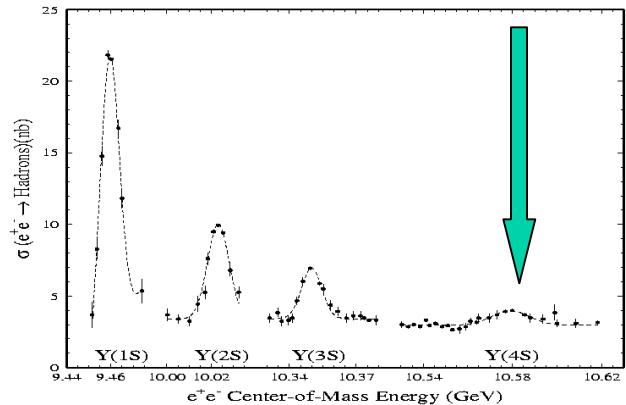
Superconducting Coil (1.5T)



Belle Detector



Kinematic variables for the $\chi_{c2}(4S)$

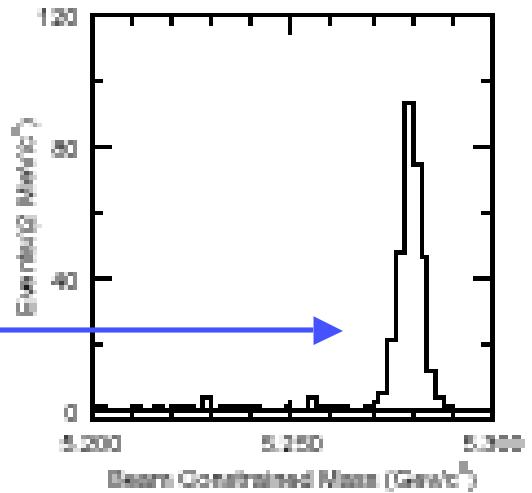


Energy difference:

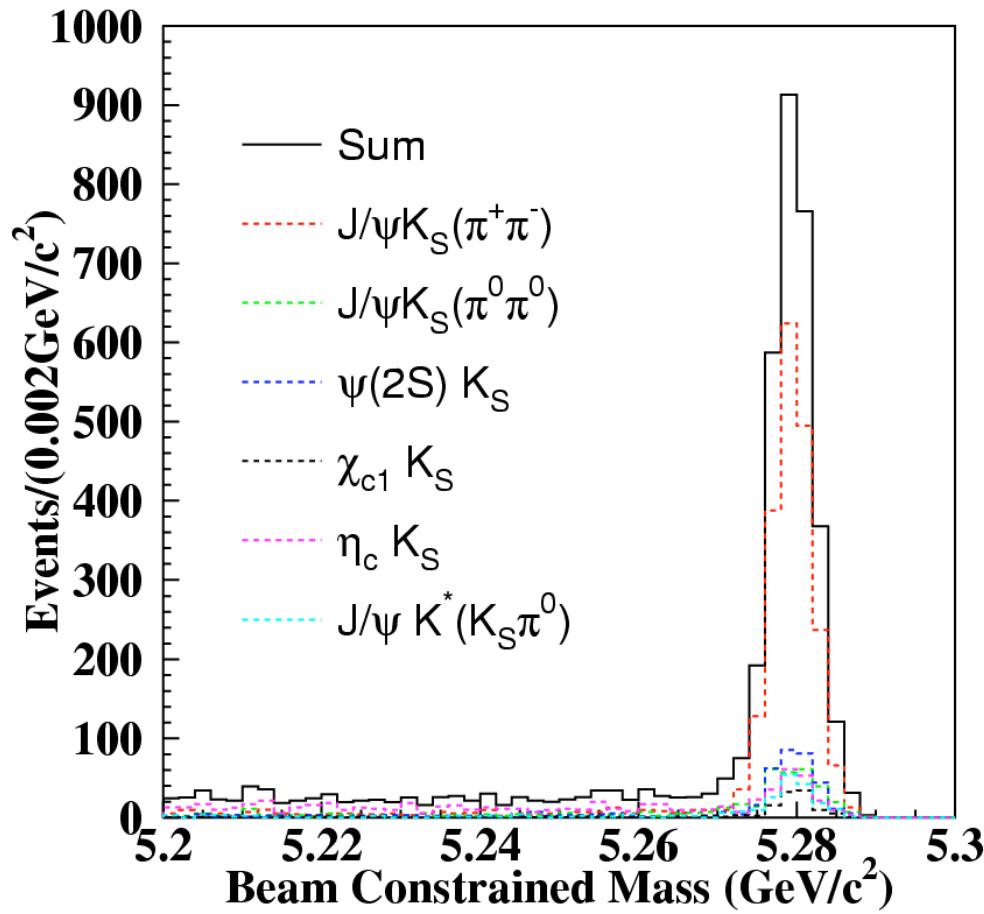
$$\Box E \equiv E_{J/\psi} + E_{K_S} \Box E_{CM} / 2$$

Beam-constrained mass:

$$m_{bc} = \sqrt{(E_{CM}/2)^2 \Box (\vec{p}_{J/\psi} + \vec{p}_{K_S})^2}$$



Belle 2003 : CP eigenstates ($b \rightarrow c\bar{c}S$)



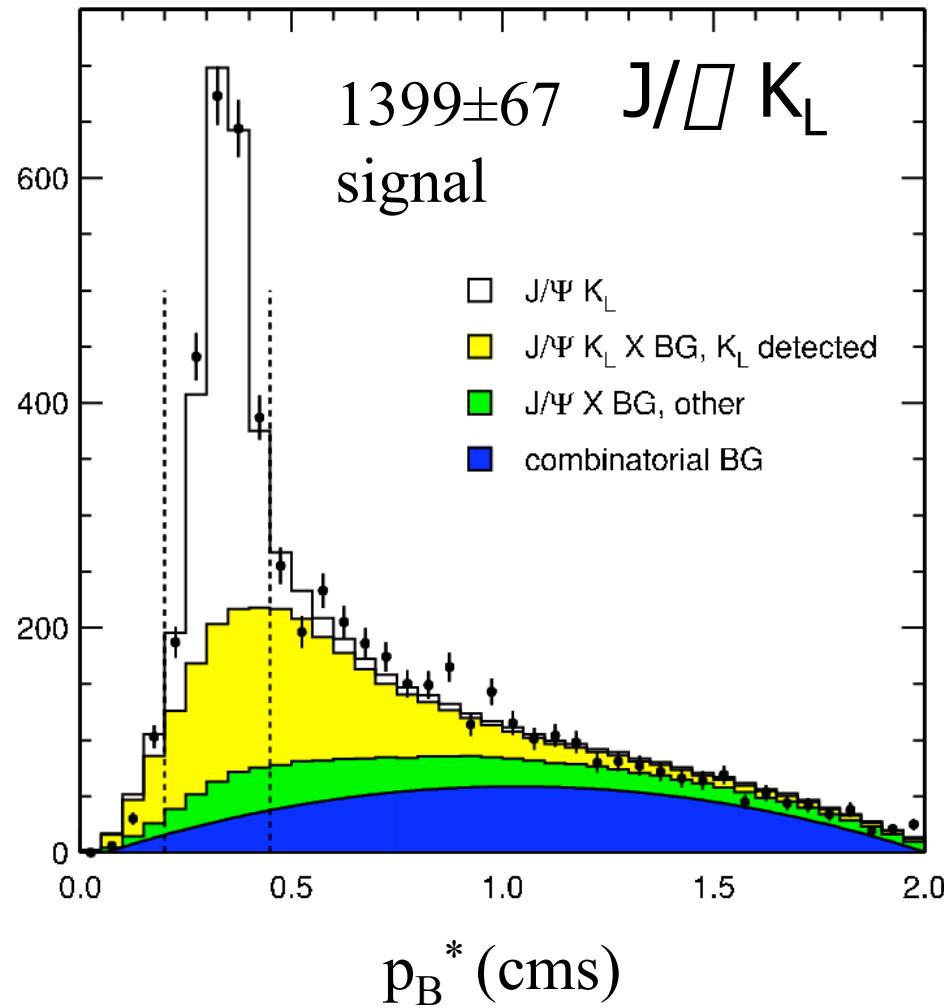
140 fb⁻¹, 152 x 10⁶ B \bar{B} pairs

Mode	N_{ev}	Purity
$J/\psi(\ell^+\ell^-)K_S^0(\pi^+\pi^-)$	1997	0.976 ± 0.001
$J/\psi(\ell^+\ell^-)K_S^0(\pi^0\pi^0)$	288	0.82 ± 0.02
$\psi(2S)(\ell^+\ell^-)K_S^0(\pi^+\pi^-)$	145	0.93 ± 0.01
$\psi(2S)(J/\psi\pi^+\pi^-)K_S^0(\pi^+\pi^-)$	163	0.88 ± 0.01
$\chi_{c1}(J/\psi\gamma)K_S^0(\pi^+\pi^-)$	101	0.92 ± 0.01
$\eta_c(K_S^0 K^- \pi^+)K_S^0(\pi^+\pi^-)$	123	0.72 ± 0.03
$\eta_c(K^+ K^- \pi^0)K_S^0(\pi^+\pi^-)$	74	0.70 ± 0.04
$\eta_c(p\bar{p})K_S^0(\pi^+\pi^-)$	20	0.91 ± 0.02
All with $\xi_f = -1$	2911	0.933 ± 0.002
$J/\psi(\ell^+\ell^-)K^{*0}(K_S^0\pi^0)$	174	0.93 ± 0.01

2911 events are used in the fit.

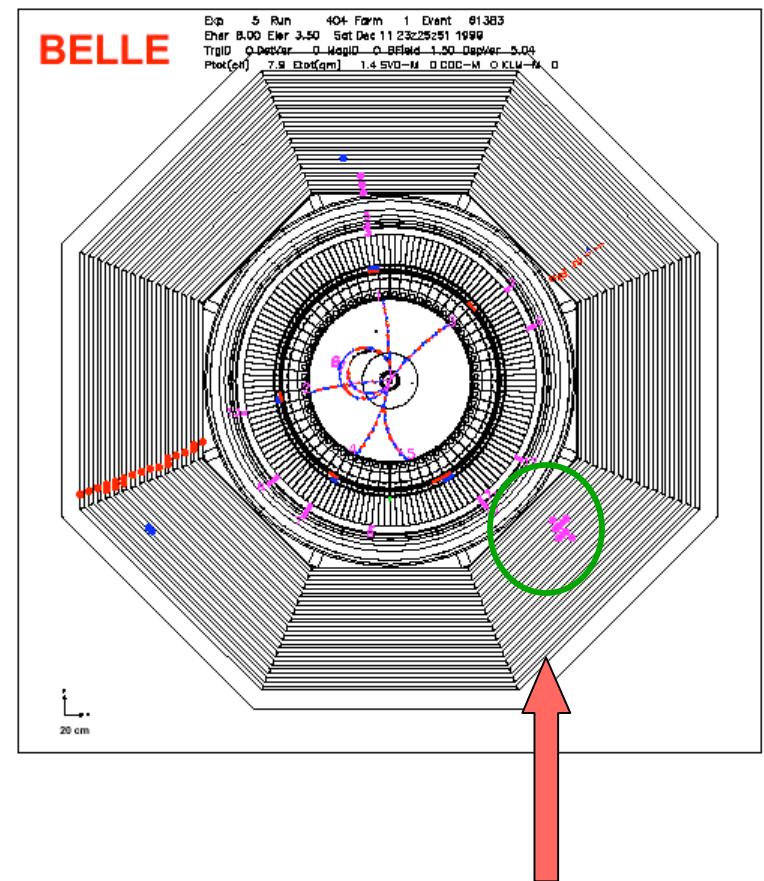
BELLE-CONF-0344

Belle 2003: $B^0 \rightarrow K_L$ signal



[2332 events with a purity of 0.60]

Event display

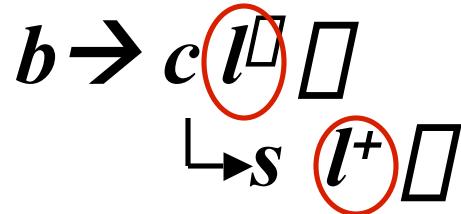


Flavor-tag the other B meson

Figure of merit(Q) = $(1 - 2 \frac{w}{w})^2$ a.k.a effective tagging efficiency

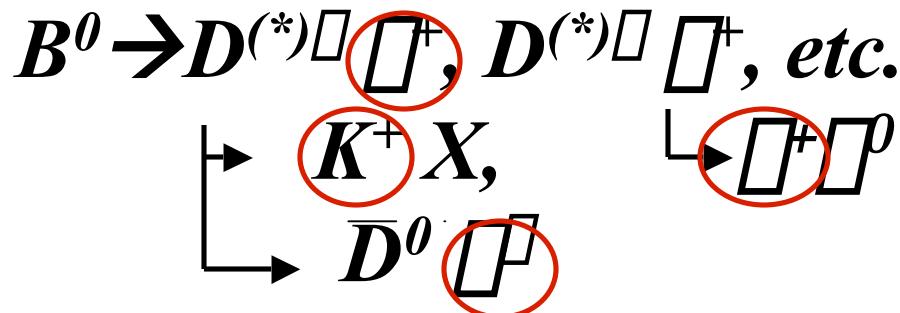
- **Inclusive Leptons:**

- **high- p_T l^-**
- **intermed- p_T l^+**



- **Inclusive Hadrons:**

- **high- p_T D^+**
- **intermed- p_T K^+**
- **low- p_T \bar{D}^0**

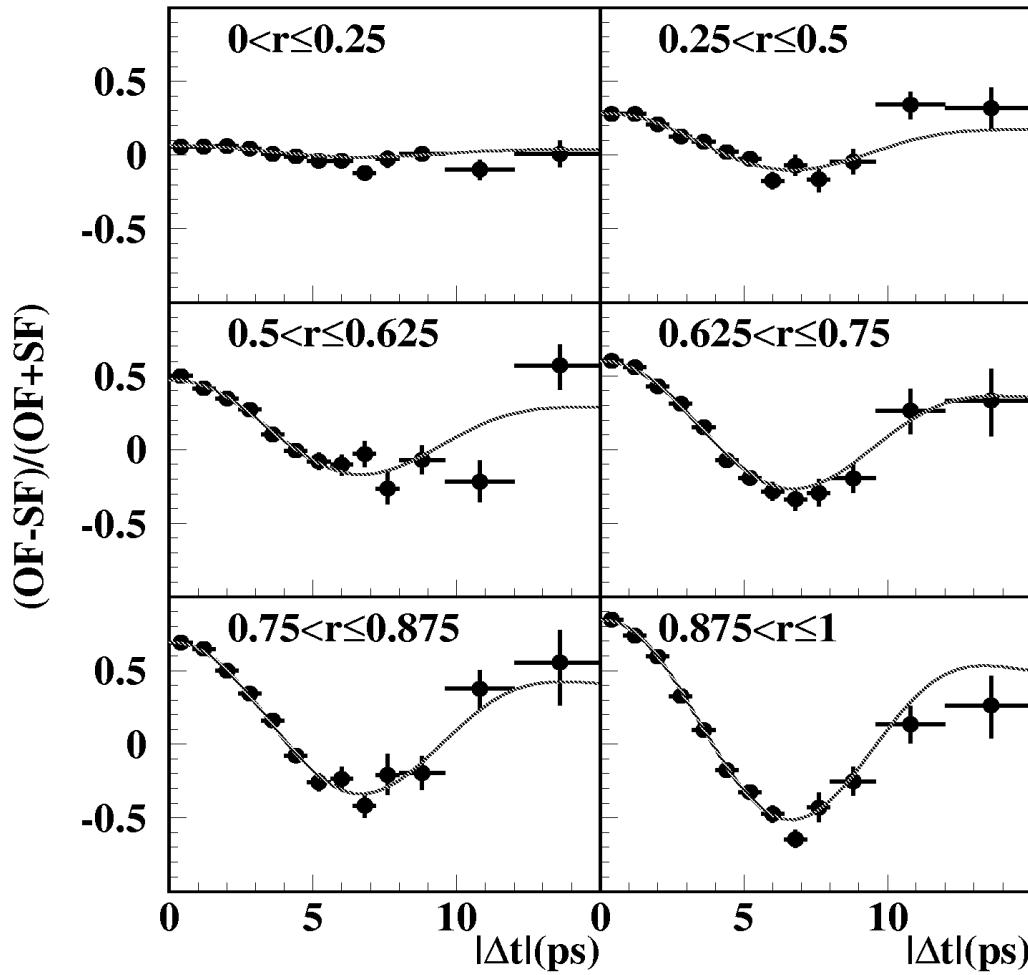


Babar: Neural Net based approach, $28.1 \pm 0.7\%$



Belle: Likelihood based approach, $28.7 \pm 0.5\%$

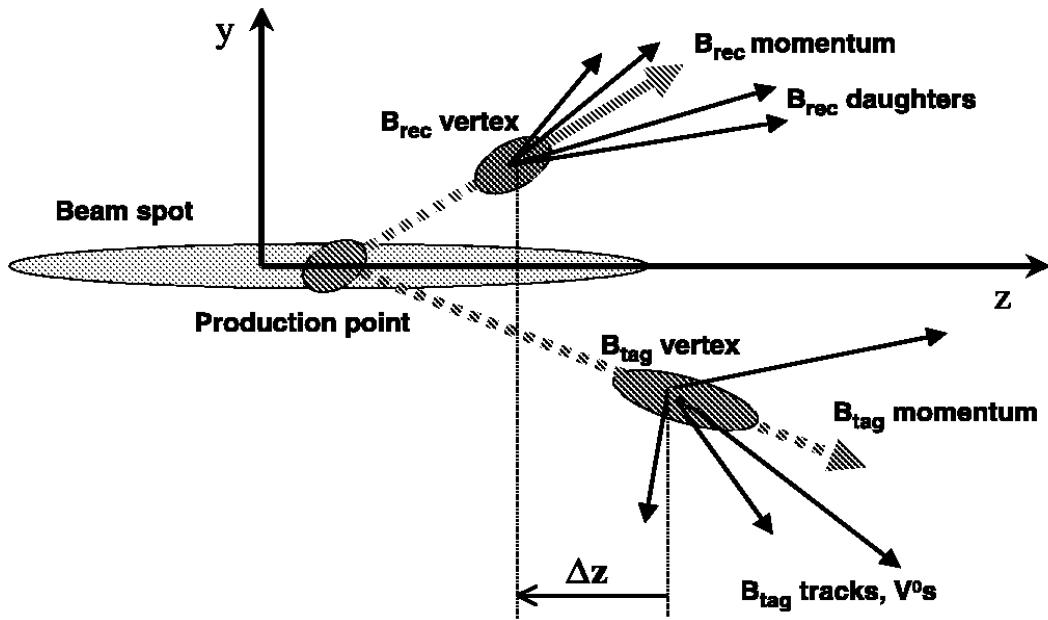
Belle Tagging Performance with $B \rightarrow D^{*+} l^- \bar{\nu}_l$



$B^0 - \bar{B}^0$ mixing

$$\begin{aligned} & (OF-SF)/(OF+SF) \\ & \sim (1-2 w) \cos(m t) \end{aligned}$$

12 r -bins, 6 divisions in r .
 B^0 and \bar{B}^0 tags treated
separately.



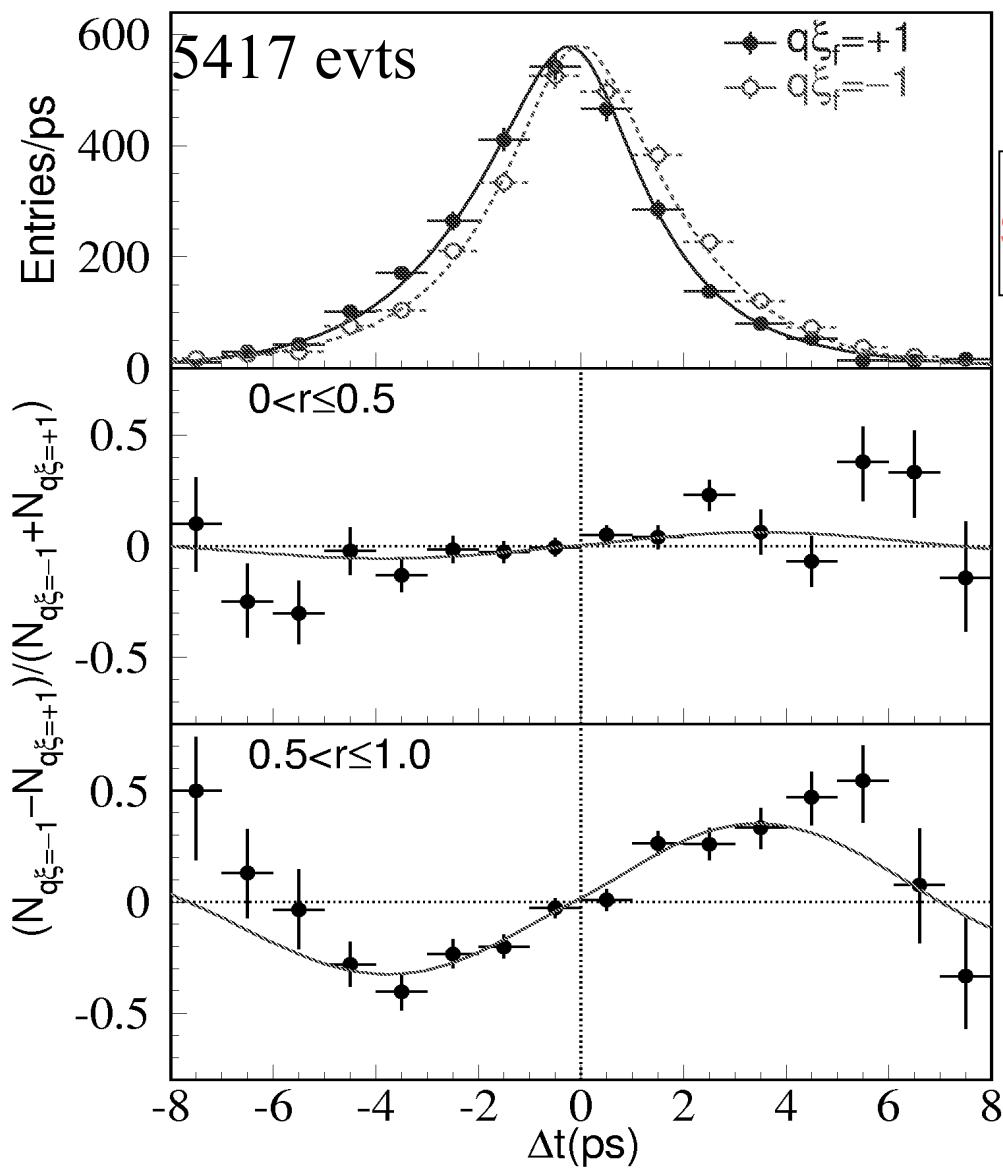
Beam spot: 110 μm x
5 μm x 0.35 cm

Both experiments use double-sided silicon strip detectors to measure Δz .

[CM Boosts] Belle: $\gamma = 0.425$ BaBar: $\gamma = 0.56$

Vertex resolutions(Belle): ($\sigma(z_{\text{cp}}) = 75 \mu\text{m}$; $\sigma(z_{\text{tag}}) = 140 \mu\text{m}$)

New measurement of $\sin 2\Delta_1$ (Belle 2003)



140 fb^{-1}

$$\sin 2\Delta_1 = 0.733 \pm 0.057 \pm 0.028$$

Poor tags

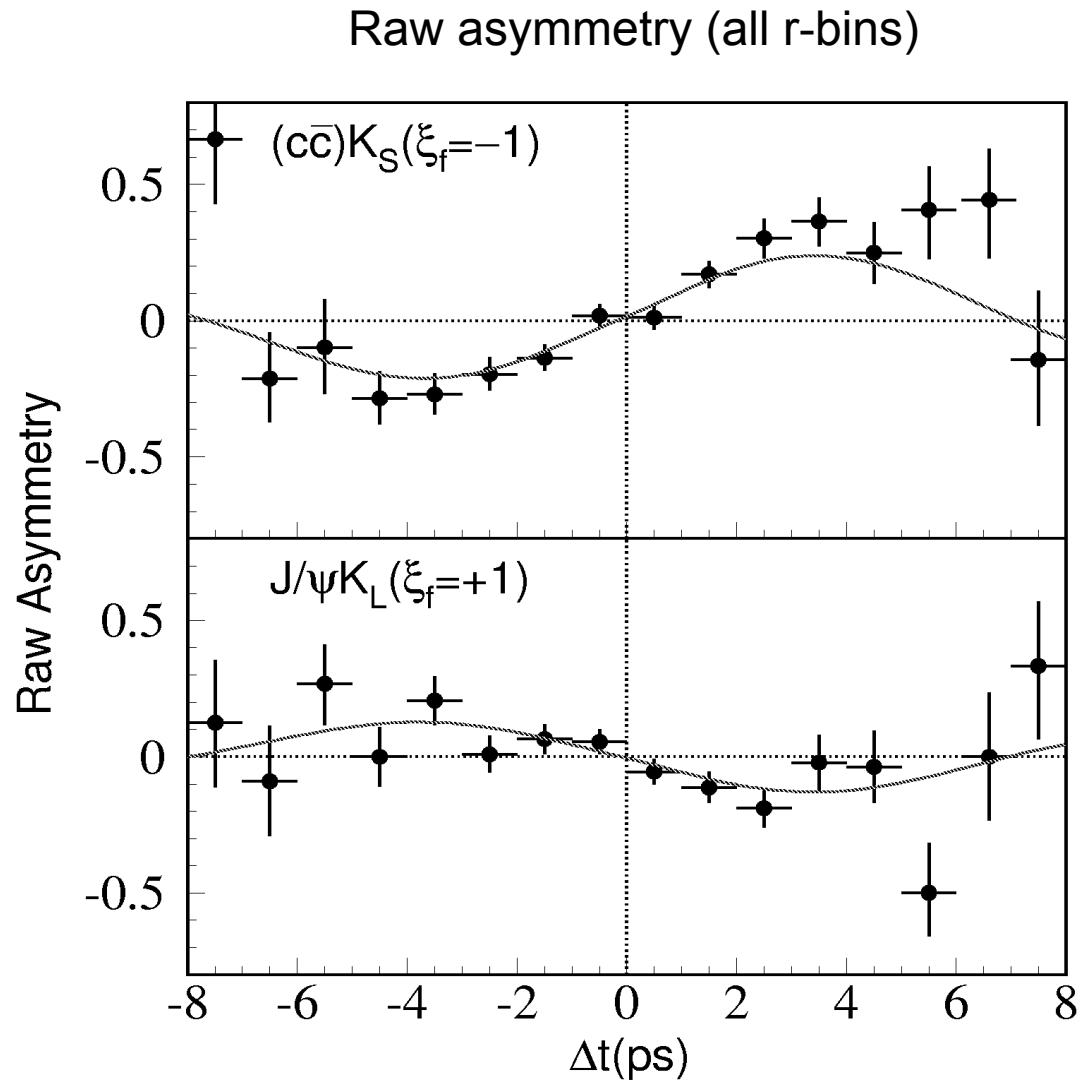
$$|\Delta_{\text{CCS}}| = 1.007 \pm 0.041 (\text{stat})$$

i.e., consistent with no direct CPV.

Good tags

BELLE-CONF-0353

Compare CP odd and CP even (Belle 2003)



CP = $\square 1$ sample

$\sin 2 \square_1$

$$= 0.73 \pm 0.06$$

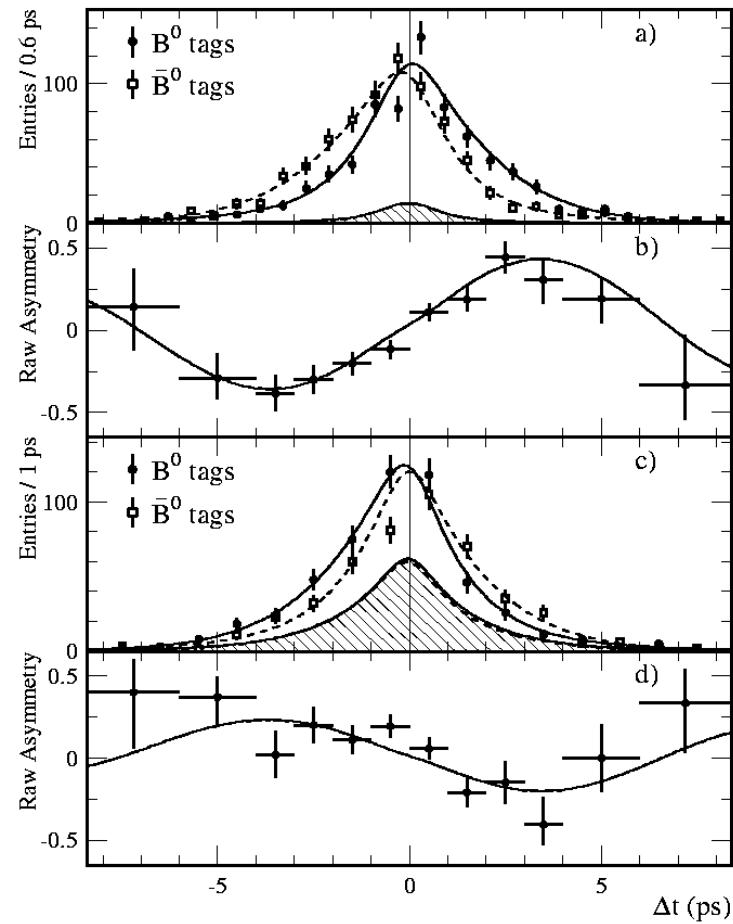
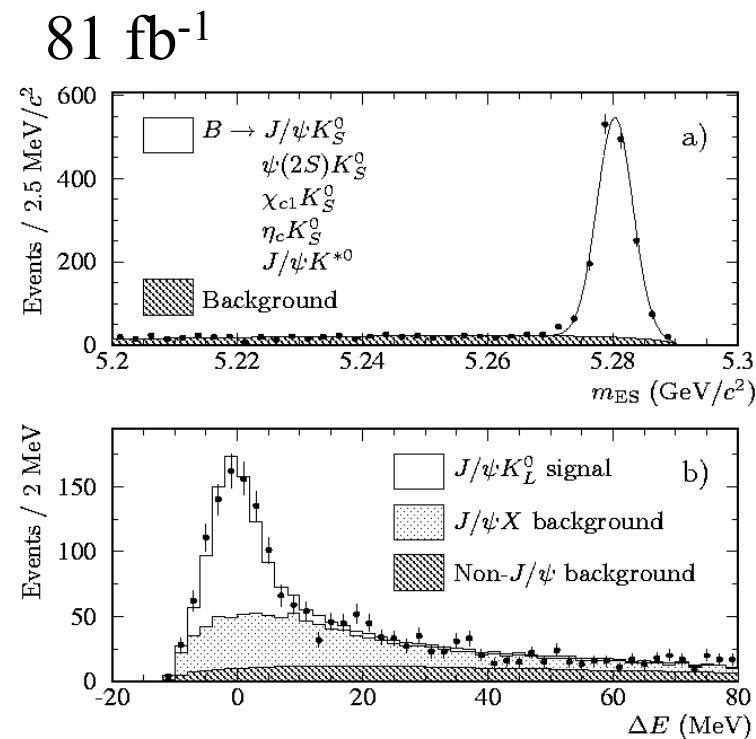
CP = +1 sample

$(B^0 \rightarrow J/\psi K_L)$

$\sin 2 \square_1$

$$= 0.80 \pm 0.13$$

Measurement of $\sin 2\beta_1$ (BaBar 2002)



CP Eigenstate Sample

hep-ex/0207042, PRL 89, 201802 (2002)

Status/history of results for $\sin(2_{-1})/\sin(2_-)$

Belle 2001: $\sin(2_{-1}) = 0.99 \pm 0.14 \pm 0.06$

Babar 2001: $\sin(2_{-1}) = 0.59 \pm 0.14 \pm 0.05$

First signals for CPV outside of the kaon sector

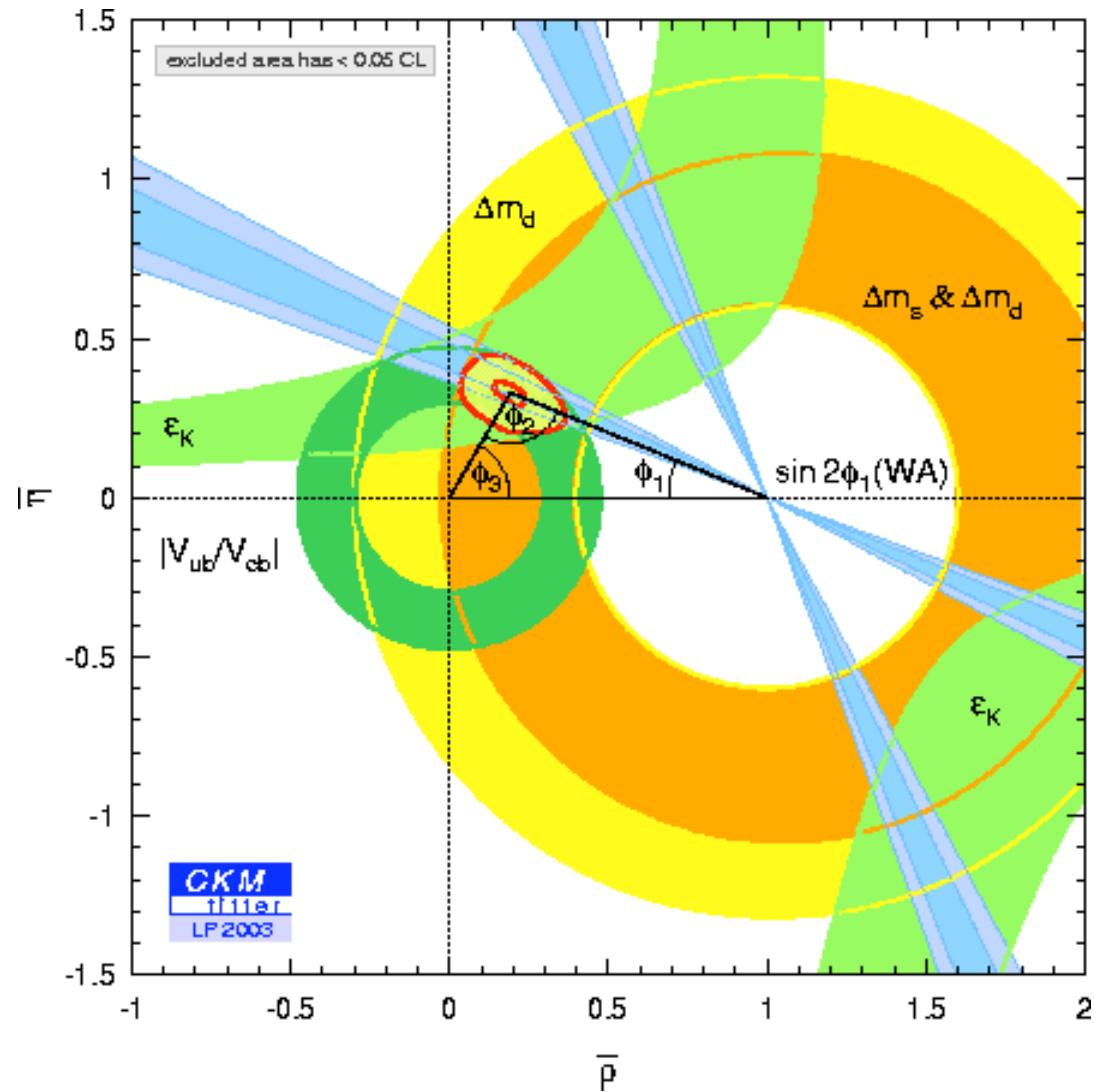


Belle 140 fb⁻¹ : $\sin(2_{-1}) = 0.733 \pm 0.057 \pm 0.028$

BaBar 81 fb⁻¹: $\sin(2_{-1}) = 0.741 \pm 0.067 \pm 0.033$

Now becoming a precision measurement

Current Belle and BaBar Results for $\sin(2\phi_1)$



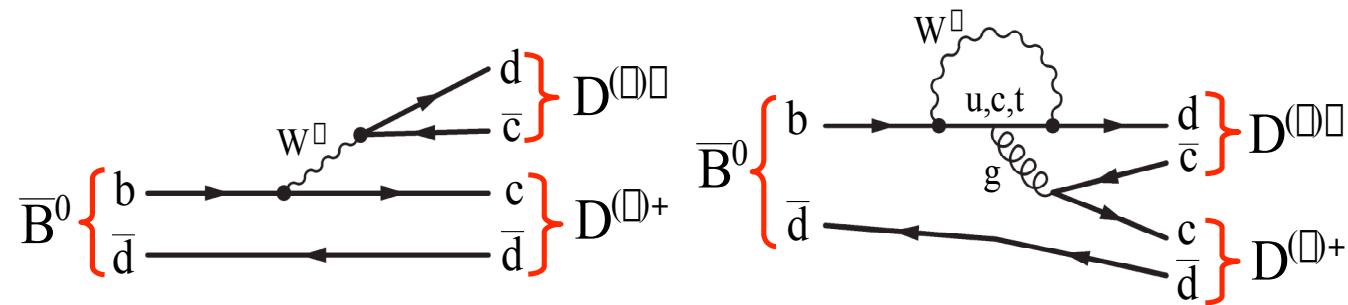
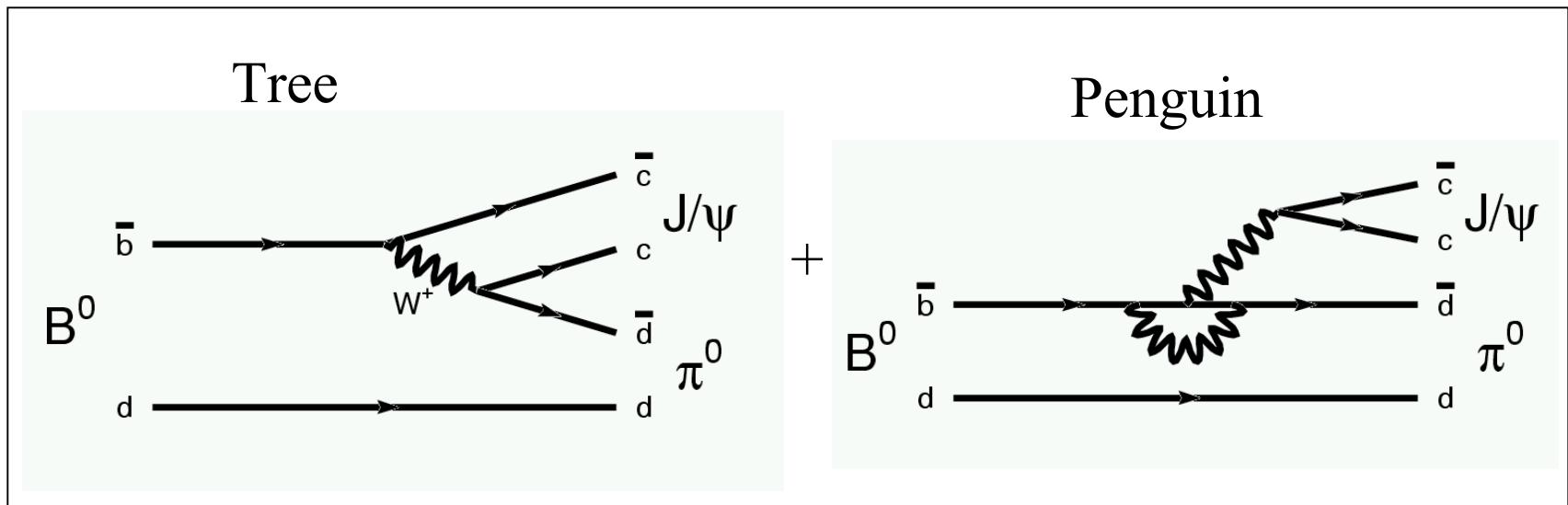
$\sin 2\phi_1$ (Belle 2003, 140 fb^{-1})
 $=0.733 \pm 0.057 \pm 0.028$

$\sin 2\phi_1$ (BaBar 2002, 81 fb^{-1})
 $=0.741 \pm 0.067 \pm 0.033$

$\sin 2\phi_1$ (New 2003 World Av.)
 $=0.736 \pm 0.049$

Thanks to A. Hoecker

CPV in $b \rightarrow (c \bar{c} d)$ decays

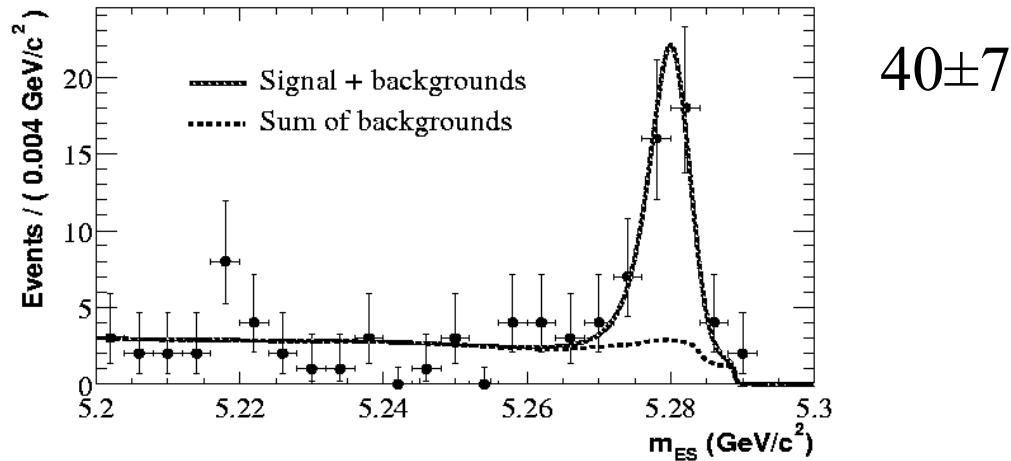


The same CPV phase as in $B \rightarrow J/\psi K_S$ but
may have **penguin pollution**.

CPV in $b \rightarrow (c \bar{c} d)$ decays: $B \rightarrow \pi^0$

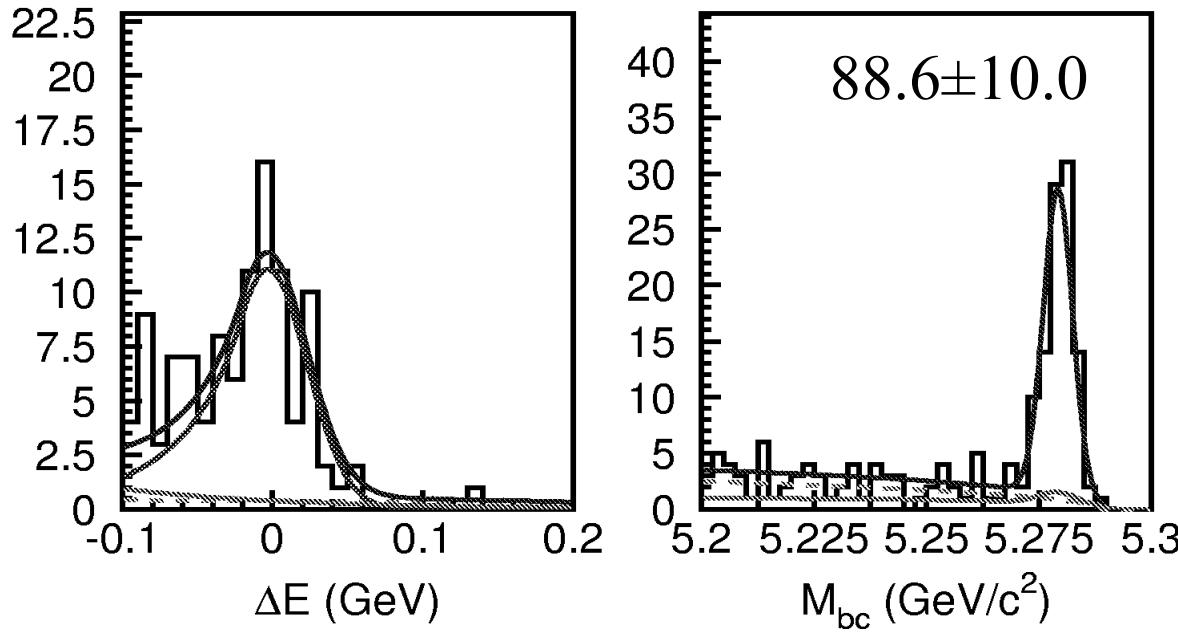
BaBar:

81 fb^{-1}



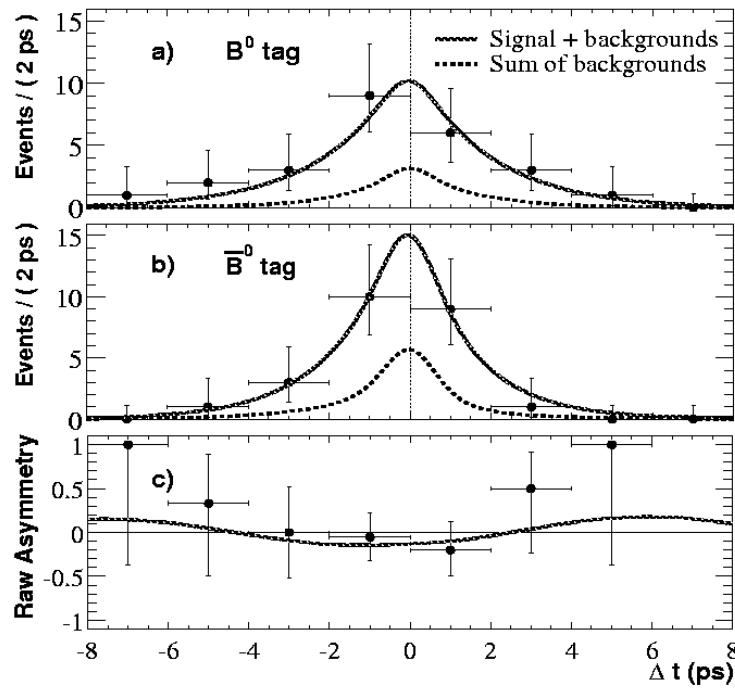
Belle:

140 fb^{-1}

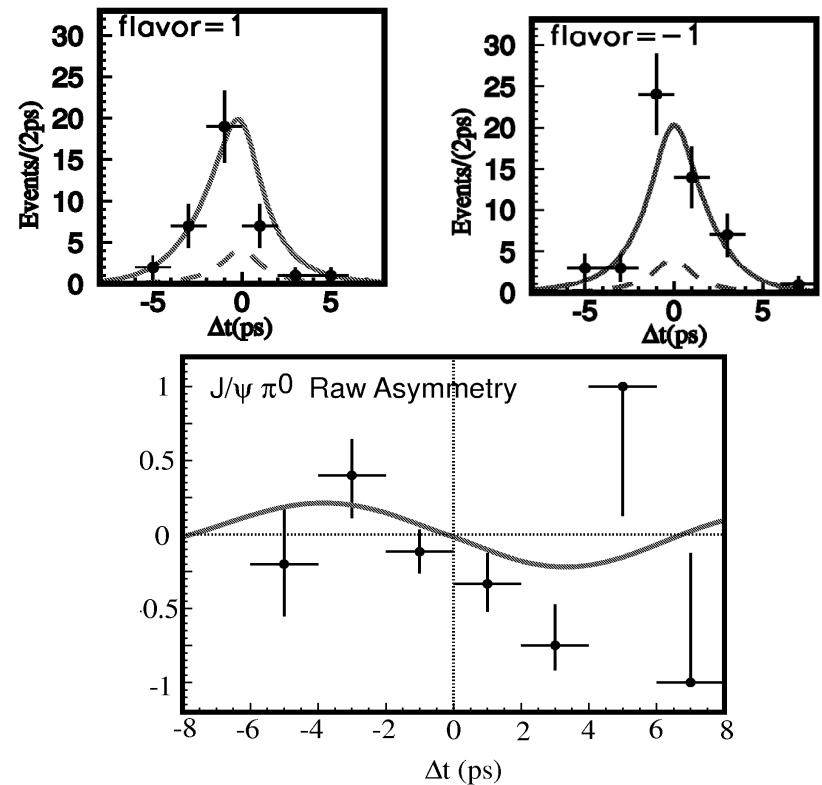


CPV in $b \rightarrow (c\bar{c} d)$ decays: $B \rightarrow \pi^0$

BaBar 2003



Belle 2003



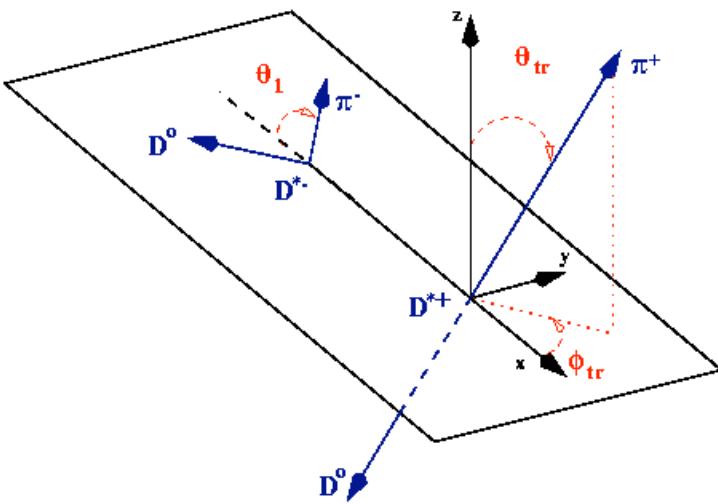
$$\sin(2_{-1\text{eff}}) = 0.05 \pm 0.49 \pm 0.16$$

hep-ex/0303018

$$\sin(2_{-1\text{eff}}) = 0.72^{+0.37}_{-0.42} \pm 0.08$$

BELLE-CONF-0342

Determination of the CP content of $B \rightarrow D^{*+} D^{*-}$



D^*D^* transversity frame

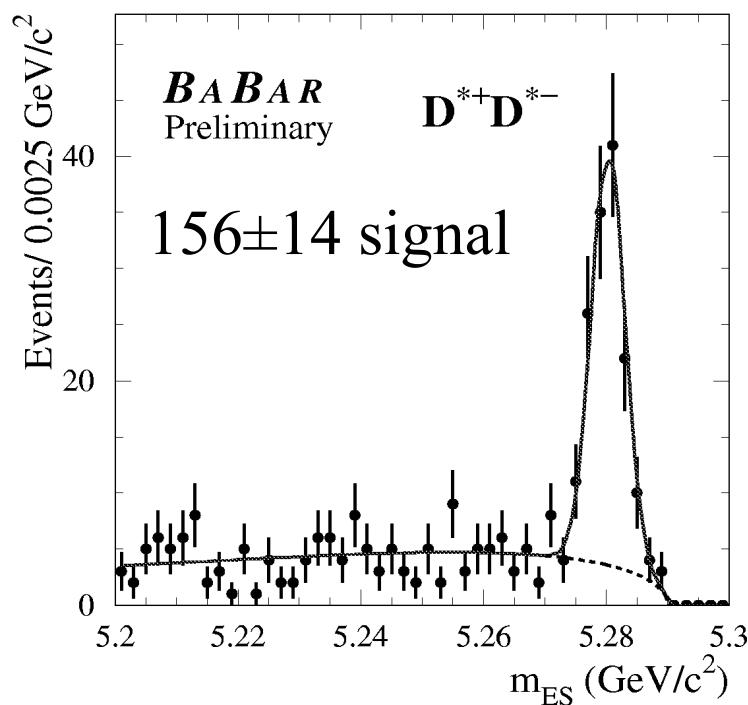
Angular PDF integrated over Φ_{tr} ,

Integrate ϕ_{tr} :

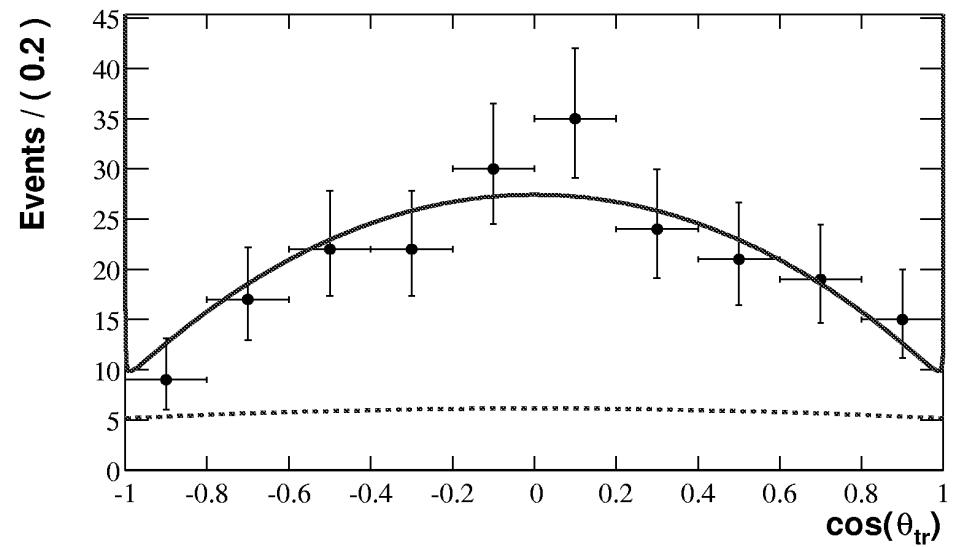
$$\frac{1}{\Gamma} \frac{d^2\Gamma}{d\cos\theta_1 d\cos\theta_{tr}} = \frac{9}{64} \frac{1}{|A_0|^2 + |A_\parallel|^2 + |A_\perp|^2} \left\{ \begin{array}{l} 2|A_0|^2(1 - \cos 2\theta_{tr})(1 + \cos 2\theta_1) \\ + |A_\parallel|^2(1 - \cos 2\theta_{tr})(1 - \cos 2\theta_1) \\ + 2|A_\perp|^2(1 + \cos 2\theta_{tr})(1 - \cos 2\theta_1) \end{array} \right\}$$

Can extract the CP content from a fit to ϕ_{tr}

Determination of the CP content of $B \rightarrow D^{+} D^{*-}$*



BaBar: $B \rightarrow D^{*+} D^{*-}$



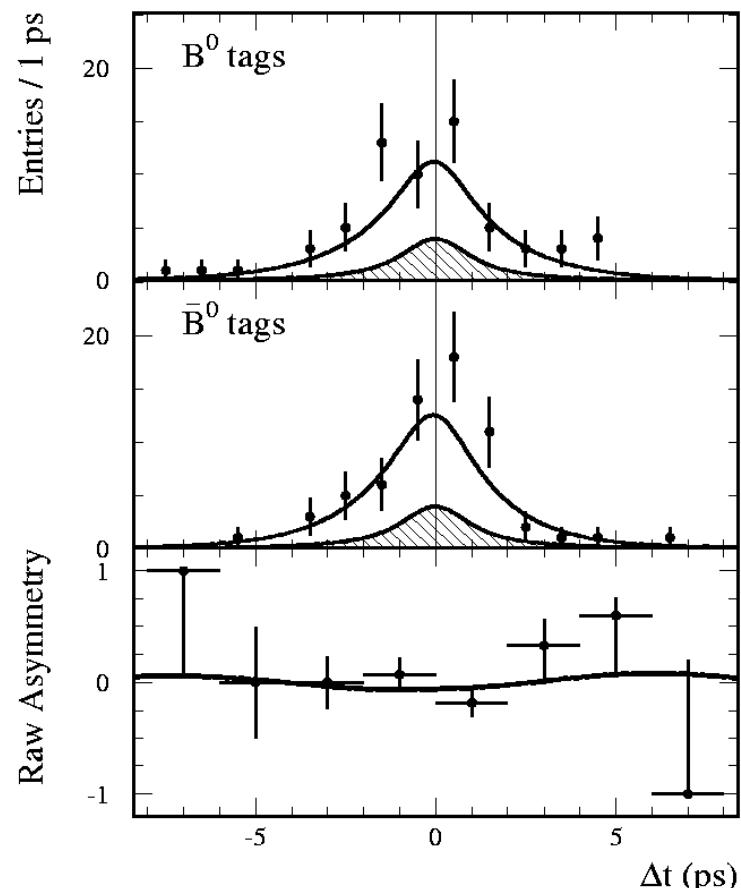
BaBar: $R_{\text{perp}} = 0.063 \pm 0.055 \pm 0.009$



Thus $B \rightarrow D^{*+} D^{*-}$ is mostly CP even

CPV in $b \rightarrow (c \bar{c} d)$ decays: $B \rightarrow D^{*+} D^{*-}$

Babar 2003



hep-ex/0303004

$$\sin(2\beta_{\text{eff}}) = -0.05 \pm 0.29 \pm 0.10$$

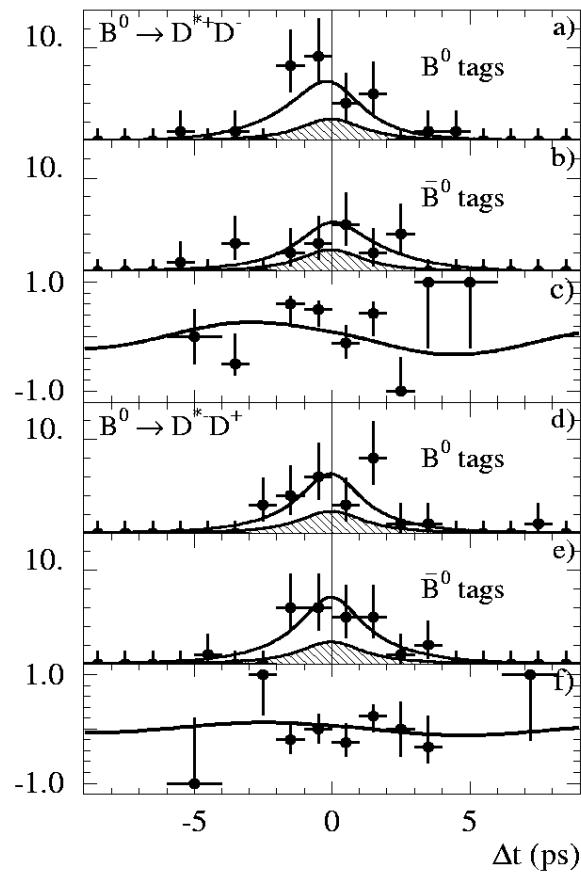
2.5 σ from $b \rightarrow c \bar{c}$ s, might indicate SM penguin contribution is present.

$$|V_{cb}| = 0.75 \pm 0.19 \pm 0.02$$

Consistent with 1 or no direct CPV

CPV in $b \rightarrow (c \bar{c} d)$ decays: $B \rightarrow D^{*+} D^-$

BaBar



$$C_{+-} = -0.47 \pm 0.40 \pm 0.12$$

$$S_{+-} = -0.82 \pm 0.75 \pm 0.14$$

$$C_{-+} = -0.22 \pm 0.37 \pm 0.10$$

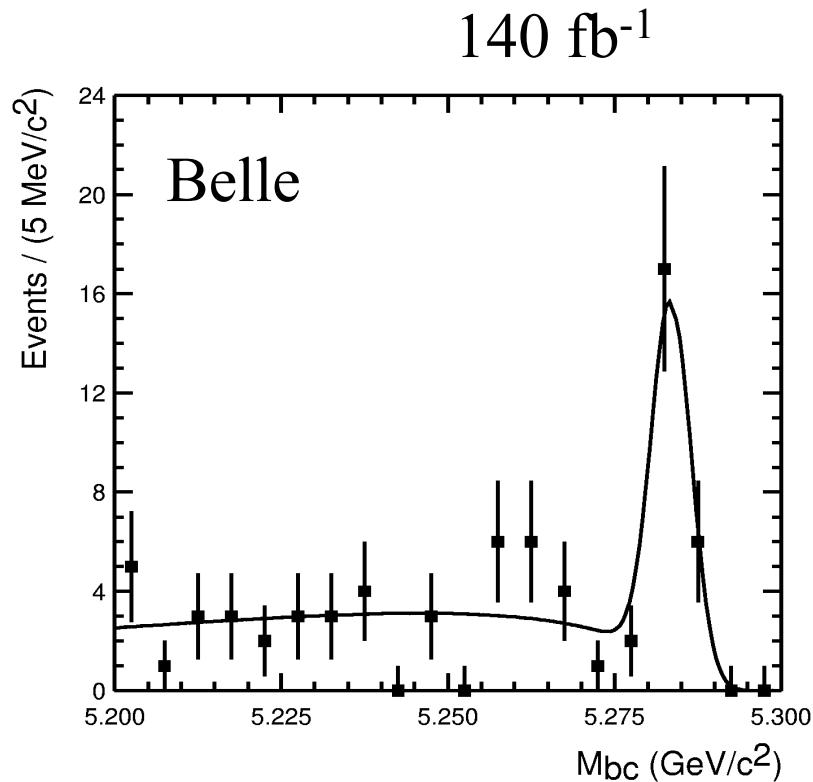
$$S_{-+} = -0.24 \pm 0.69 \pm 0.12$$

In the limit of no penguins and factorization.

$$S_{-+} = S_{+-} = -\sin(2\alpha_1) \text{ and } C_{-+} = C_{+-} = 0$$

hep-ex/0306052

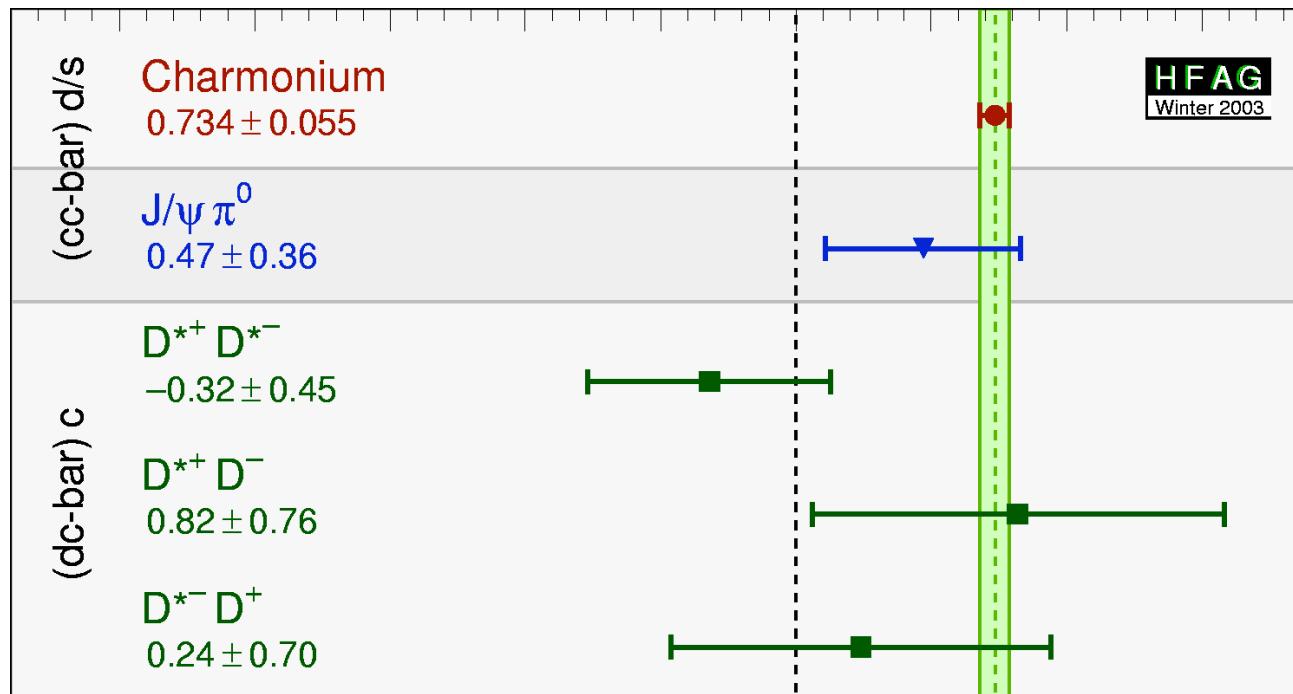
Belle 2003: Observation of $D^+ D^-$



- Yield : 24.3 ± 6.0
- Significance : 5.0
- Efficiency : 7.95 %
- BF : $(2.46 \pm 0.61 \pm 0.42) \times 10^{-4}$
- Control sample [$B \rightarrow D_s D$]

This $b \rightarrow c \bar{c} d$ mode can also be used in the future for time dependent CPV analyses.

Summary of CPV in $b \rightarrow (c \bar{c} d)$ decays:



Old Belle
value used

Errors are large for these modes so that it is difficult to verify whether there is large penguin pollution. There is a 2.5 “hint” for penguin pollution in Babar’s result for $B \rightarrow D^ \bar{D}^*$*

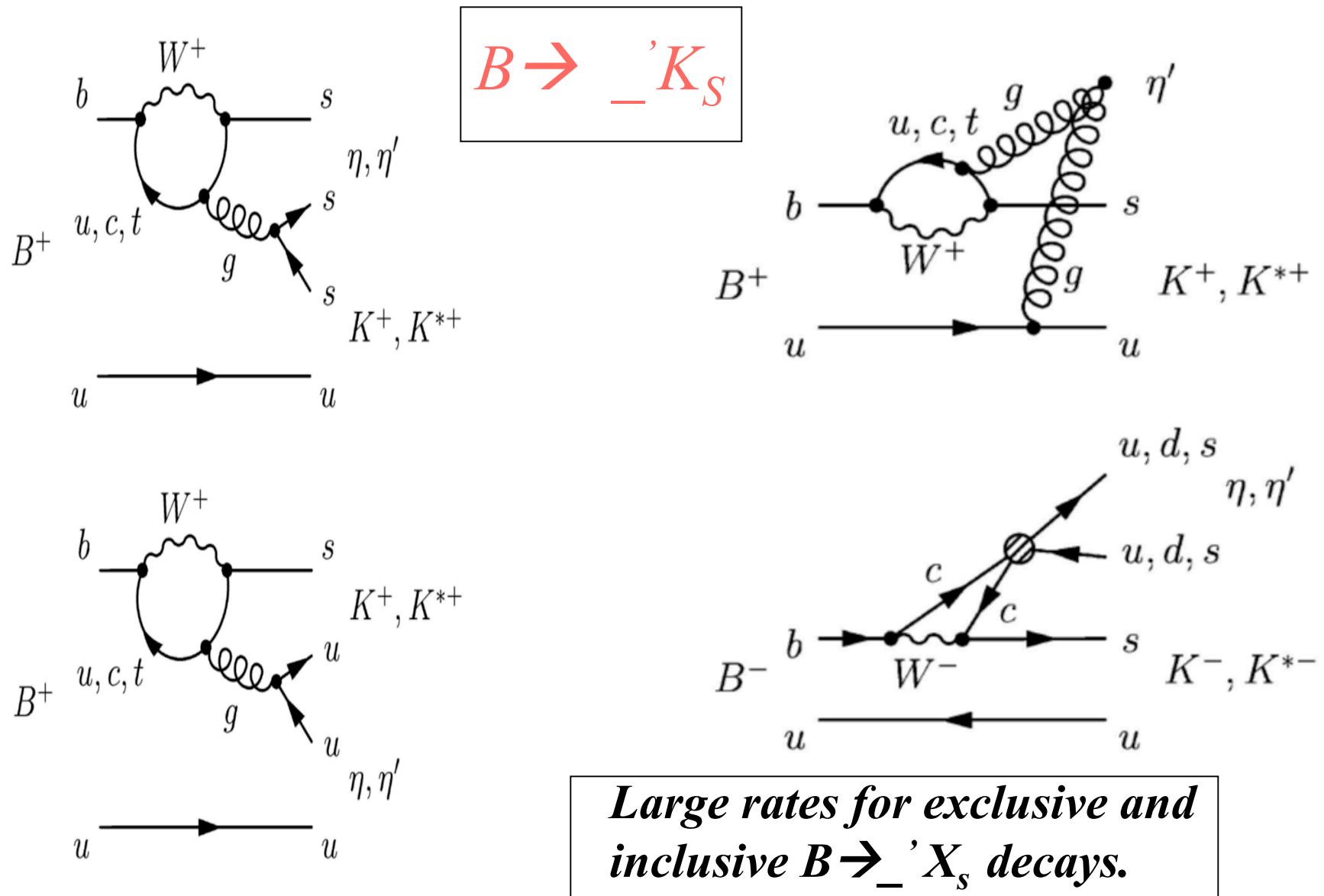
Dreams of New Physics with CPV in rare B decays.



In the SM, for
pure $b \rightarrow s$ modes

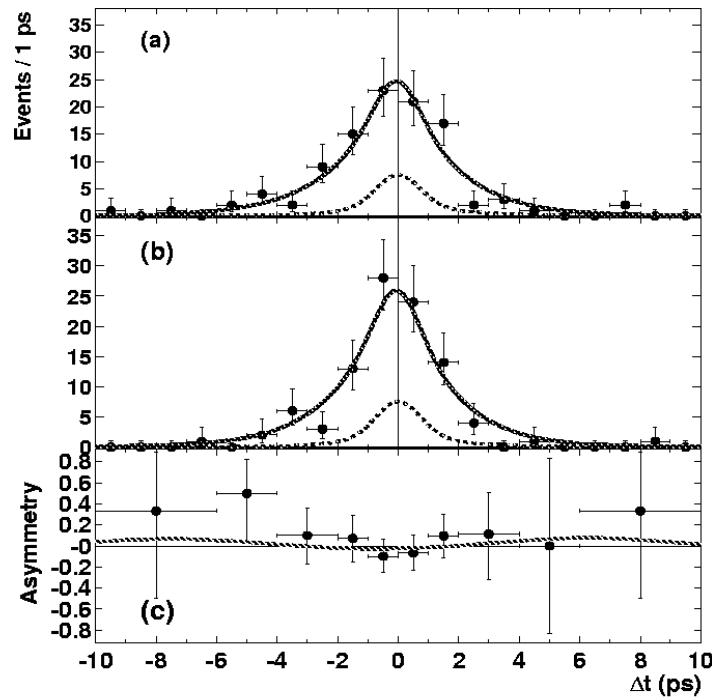
$$\begin{aligned}\sin(2_{-1})^{\text{eff}} &= \\ \sin(2_{-1})(B \rightarrow \bar{s} K_S) &\end{aligned}$$

Hunting for new phases in $b \rightarrow s$ penguins



Search for New Physics in the $B \rightarrow \eta' K_S$ decay

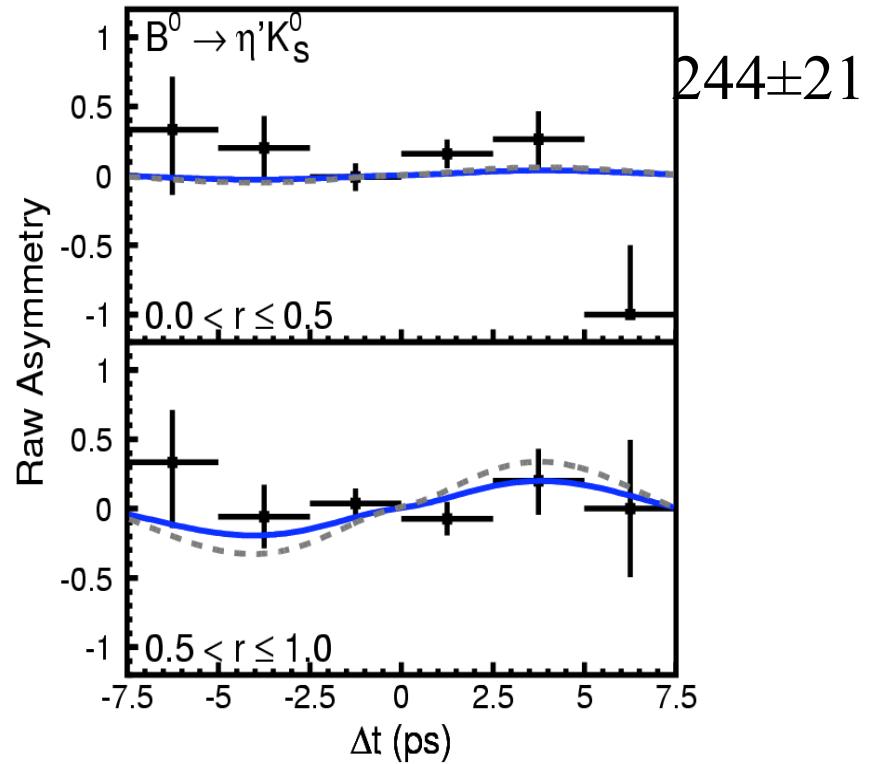
BaBar 2003 [81 fb^{-1}]



Babar: $S_{\eta' K_S} = 0.02 \pm 0.34 \pm 0.03$

($A = -0.10 \pm 0.22 \pm 0.03$)

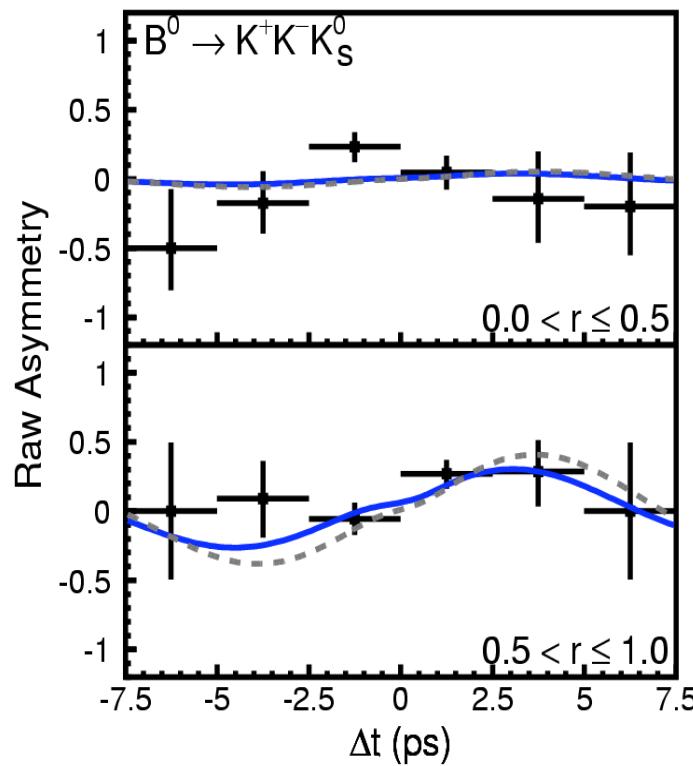
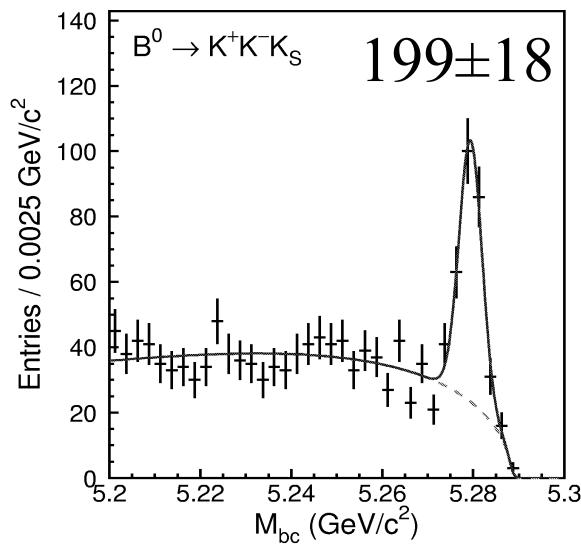
Belle 2003 [140 fb^{-1}]



Belle: $S_{\eta' K_S} = 0.43 \pm 0.27 \pm 0.05$

($A = -0.01 \pm 0.16 \pm 0.04$)

Current WA: $\sin(2\alpha_1) = 0.731 \pm 0.056$



Belle 2003:[140 fb⁻¹]

CPV in the $B \rightarrow K^+ K^- K_S$ ($b \rightarrow s$) penguin decay. (no K_S)

$$S_{KKK_S} = 0.51 \pm 0.26 \pm 0.05$$

$+0.18$
 -0.00

The third error is due to uncertainty in the CP content.

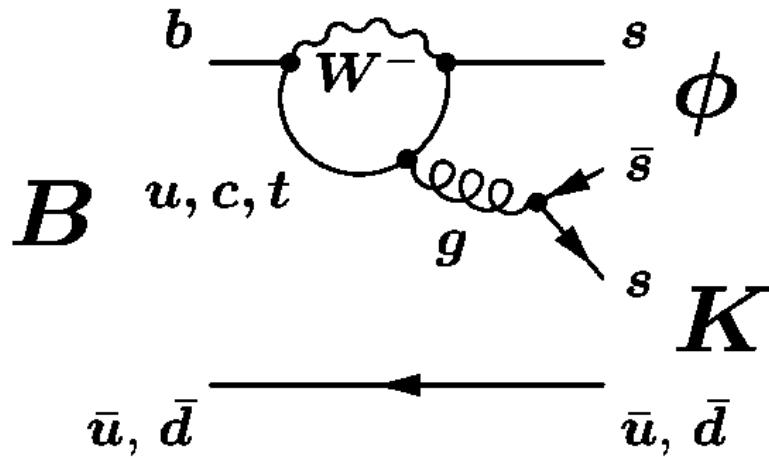
$$(A = -0.17 \pm 0.16 \pm 0.04)$$

In the absence of New Physics, $S_{KKK_S} = \sin(2\pi f_1)$

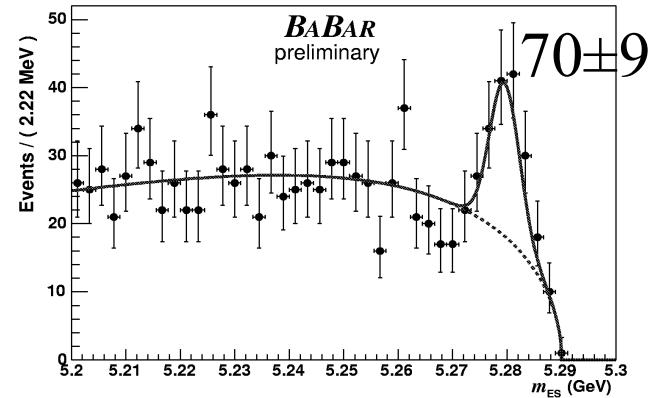
Current WA: $\sin(2\pi f_1) = 0.731 \pm 0.056$

Hunting for phases from new physics

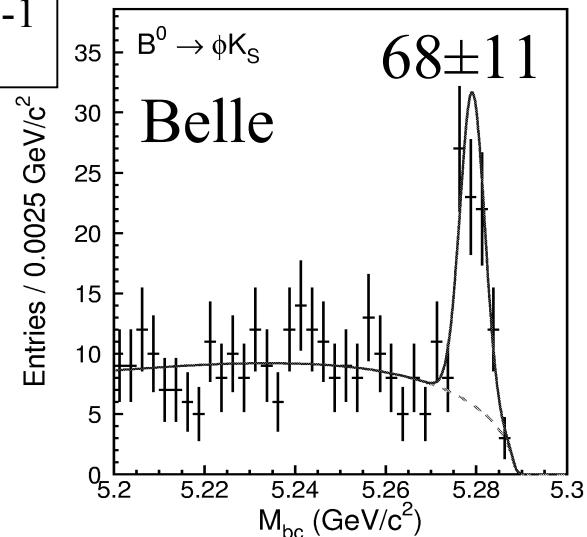
Theoretically
cleanest example:



110 fb⁻¹

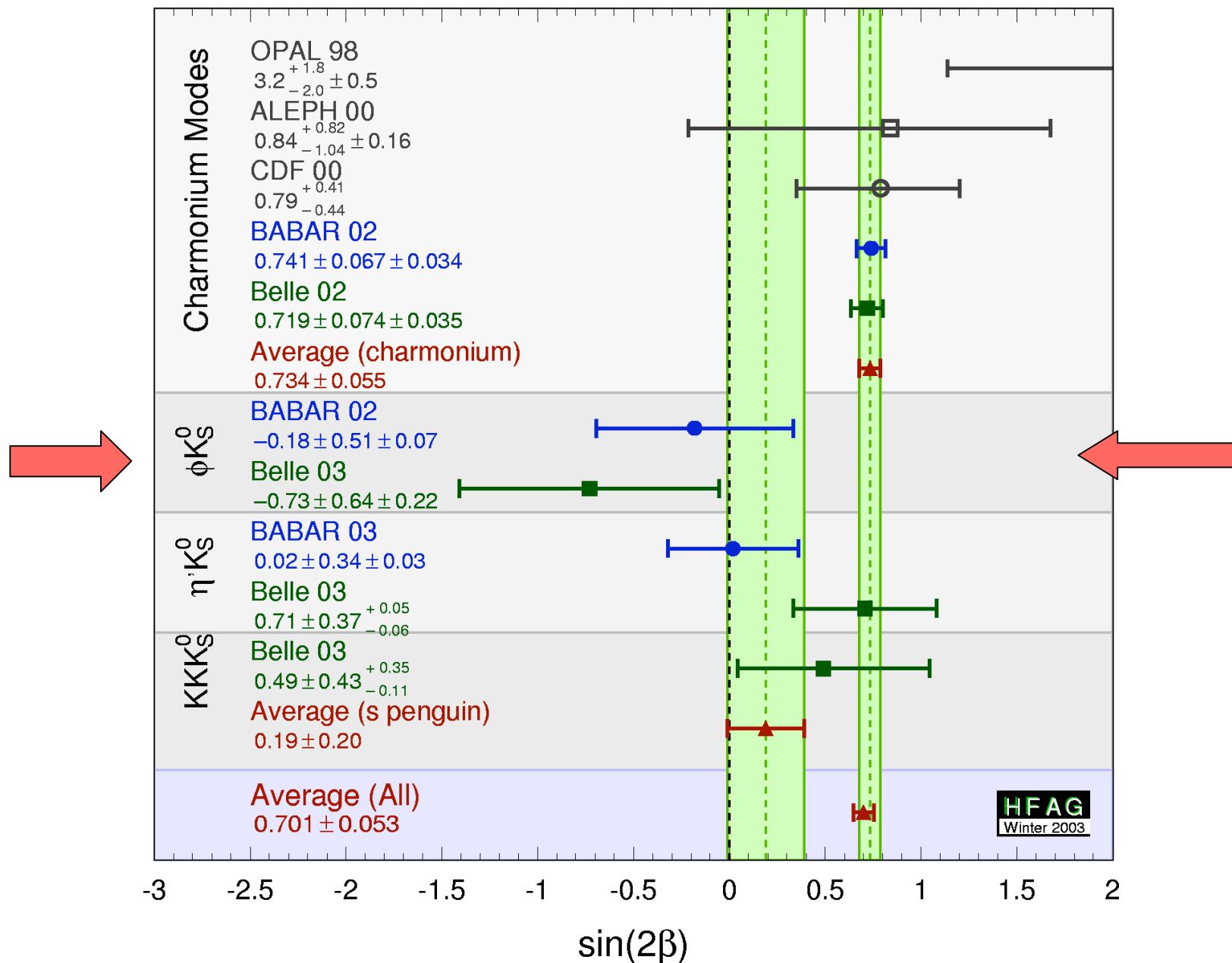


140 fb⁻¹



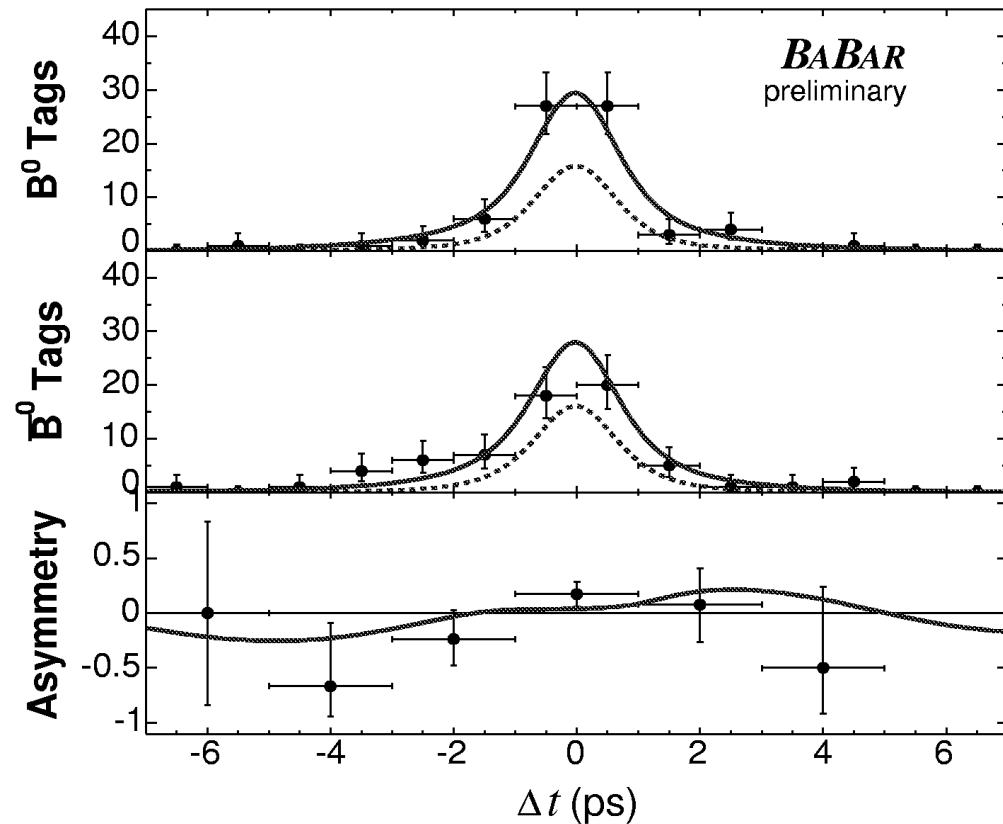
In the SM, $\sin(2_{-1})^{\text{eff}} = \sin(2_{-1}) (B \rightarrow K_S)$

2002 Status of new phases in $b \rightarrow s$ penguins



BaBar 2003: CPV in $B \rightarrow K_S$

BaBar 2003: 110 fb^{-1}

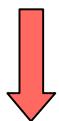


$$(A = 0.38 \pm 0.37 \pm 0.12)$$

BaBar 2003: $\sin 2\beta_{1\text{eff}}(K_S) = +0.45 \pm 0.43 \pm 0.07$

BaBar 2003: $B \rightarrow K_S$ Systematic Issues

81 fb⁻¹: $\sin 2_{\text{eff}}(_K_S) = -0.18 \pm 0.51 \pm 0.09$



110 fb⁻¹: $\sin 2_{\text{eff}}(_K_S) = +0.45 \pm 0.43 \pm 0.07$

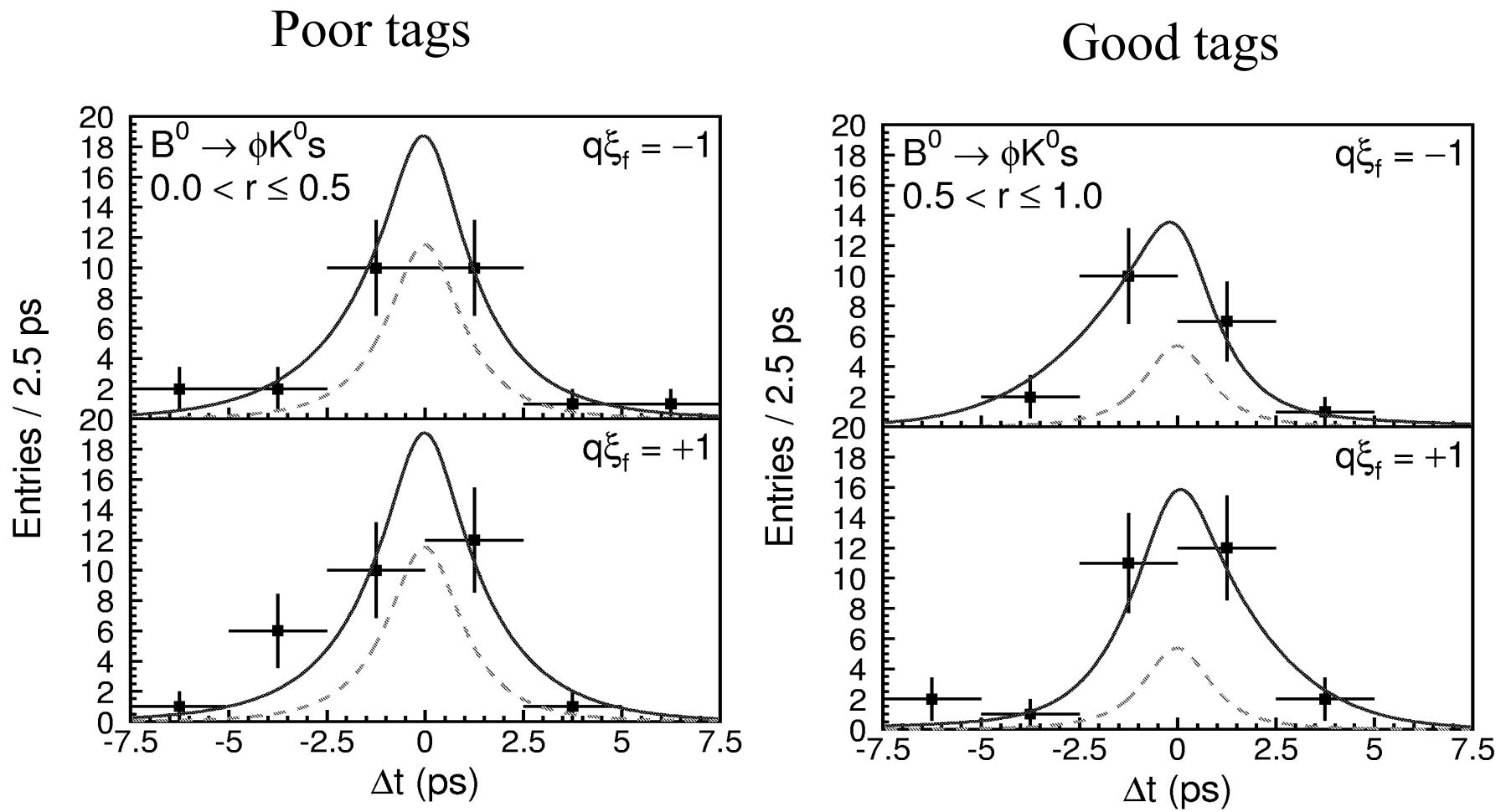
Data size increased and was reprocessed. Extensive checks with data and Toy MC. The large change is attributed to a 1_ statistical fluctuation.

BaBar 2003: $B \rightarrow K_S$ Systematic Issues

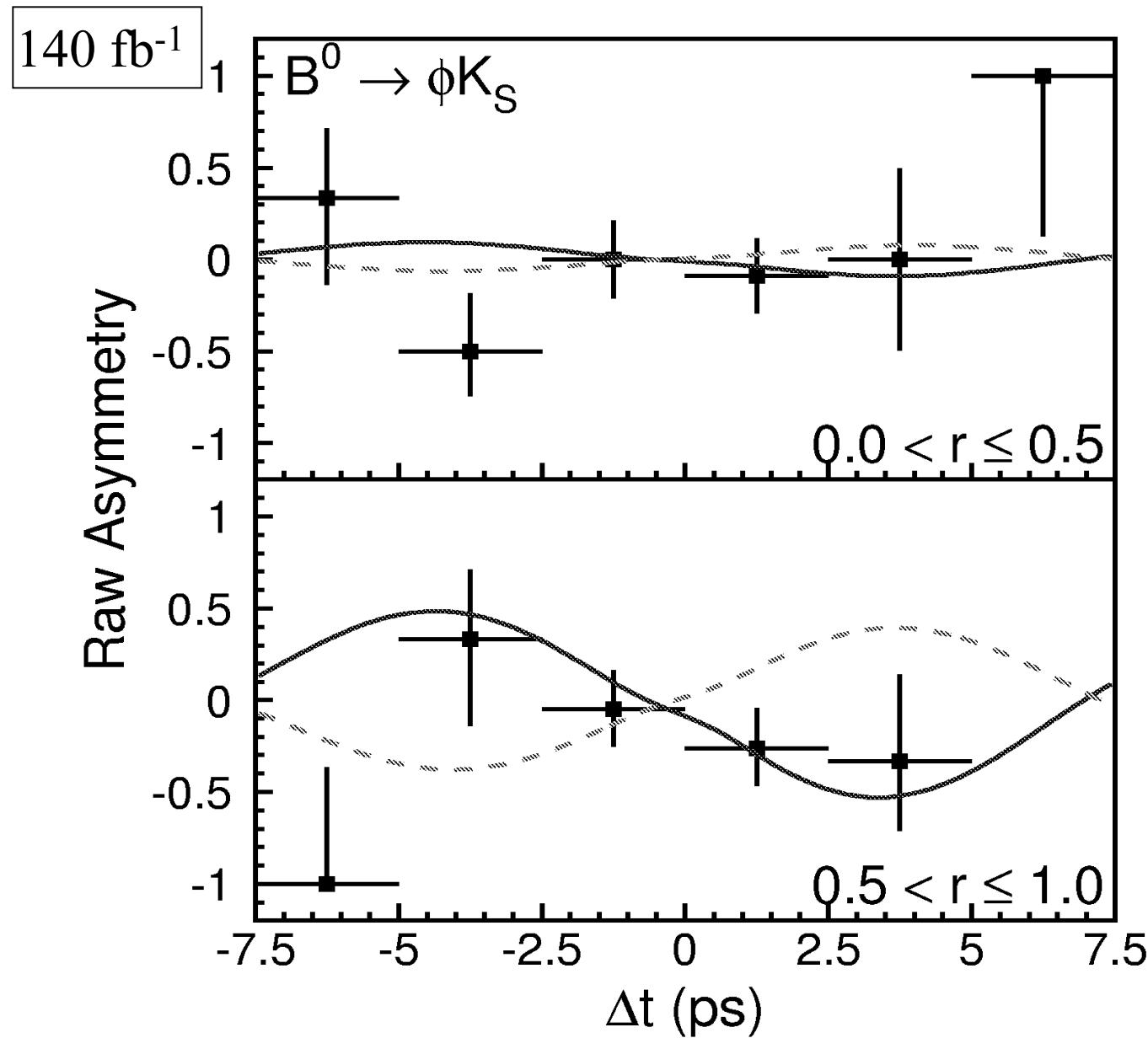
Systematic uncertainty due to	<i>S</i>	<i>C</i>
Fit bias	0.04	0.05
Event yield	0.01	0.05
Parametrization of Δt resolution	0.03	0.02
Background composition/ <i>CP</i> asymmetry	0.03	0.05
m_{ES} background parameterization	0.02	0.05
Uncertainties in the SVT alignment	0.01	0.01
Beamspot position	0.01	0.01
PDFs for the event yield in signal and background	0.004	0.04
Potential S-wave contamination	0.002	0.015
B^0/\bar{B}^0 efficiency difference	0.002	0.02
Doubly-Cabibbo-suppressed decays	0.009	0.027
Total	0.07	0.12

Systematics are small and well understood from $b \rightarrow c$ $c\bar{b}$ s studies

Belle 2003: CP Asymmetry in $B \rightarrow K_S$



Belle 2003: CP Asymmetry in $B \rightarrow K_S$

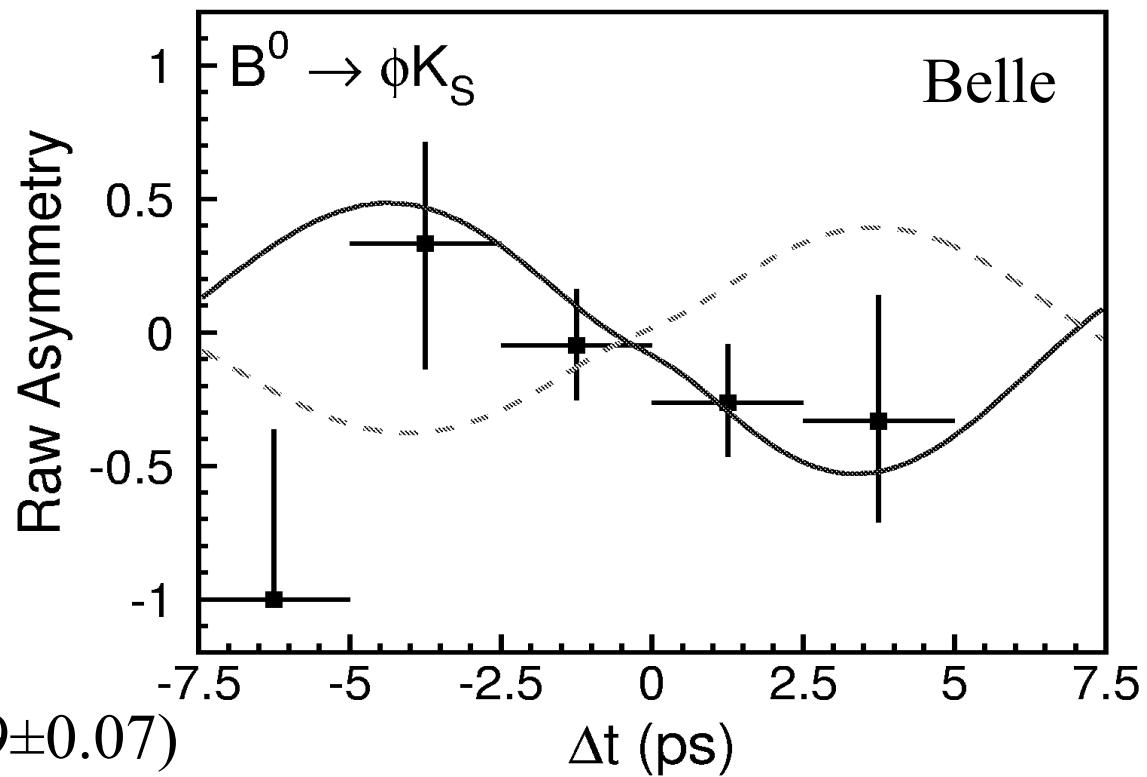


Poor flavor
tags

Good flavor
tags

Belle 2003: CP Asymmetry in $B \rightarrow K_S$

140 fb⁻¹



$$(A = -0.15 \pm 0.29 \pm 0.07)$$

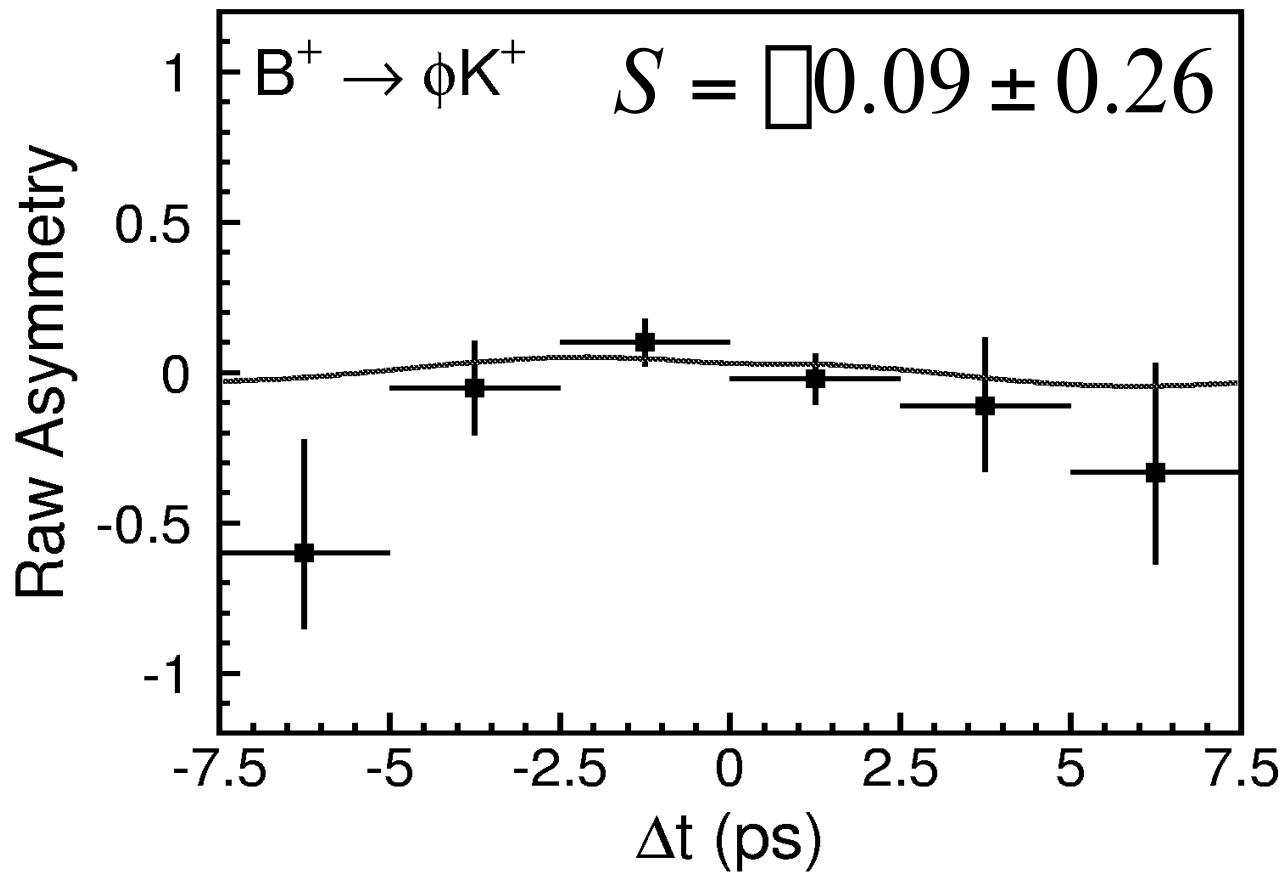
$$\text{Belle: } \sin 2_{\text{eff}} = -0.96 \pm 0.50^{+0.09}_{-0.11}$$



3.5 off

Current WA: $\sin(2_{\text{eff}}) = 0.731 \pm 0.056$

Belle 2003: CP Fit for $B^\pm \rightarrow K^\pm$ Control Sample



No sin-like
asymmetry.

Systematic issues in the Belle Measurement of CPV in $B \rightarrow K_S$

CP in the background: $(7.2 \pm 1.7)\% K \bar{K} K_S$ (measured)
 $: (1.6^{+1.9}_{-1.5})\% f_0 K_S$

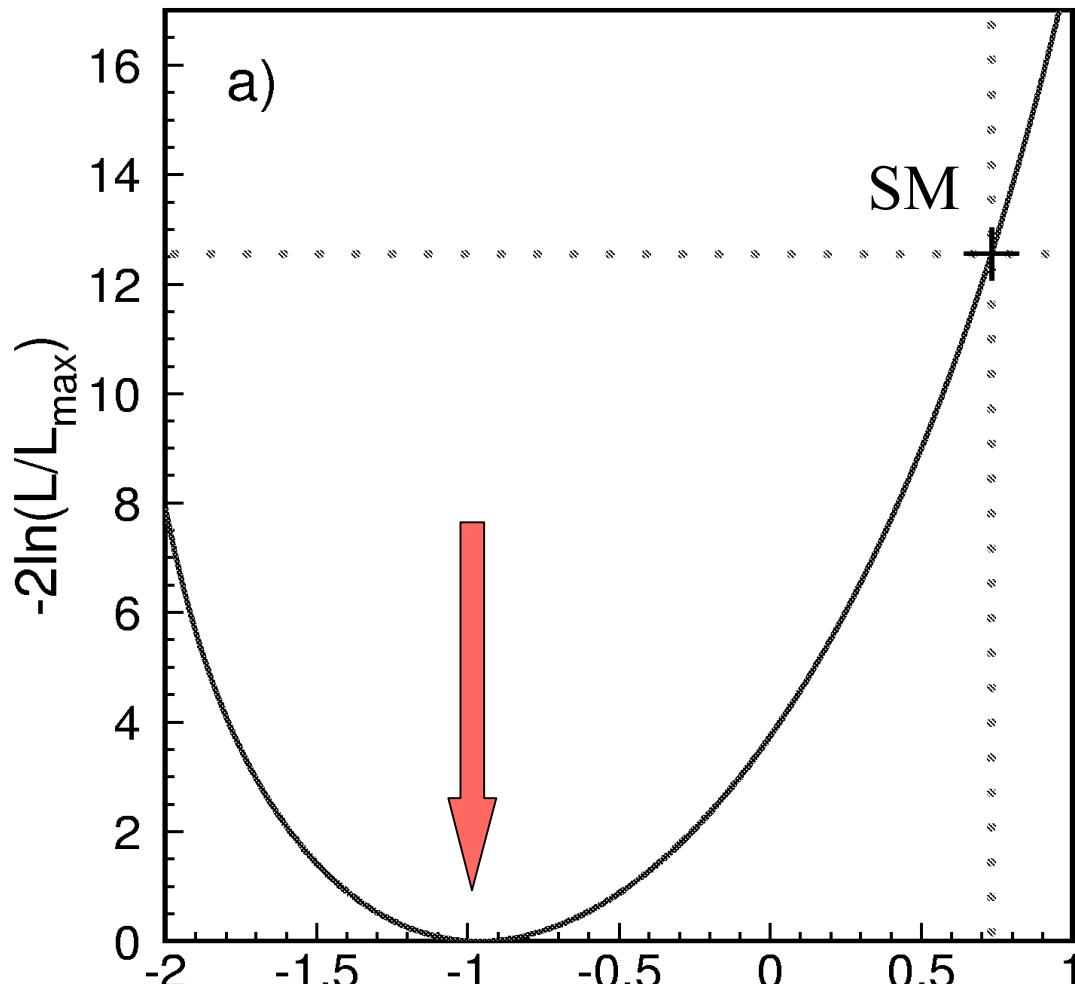
These effects are included in the systematic error

Correlation between A and S ?

$A = -0.15 \pm 0.29 \pm 0.07$

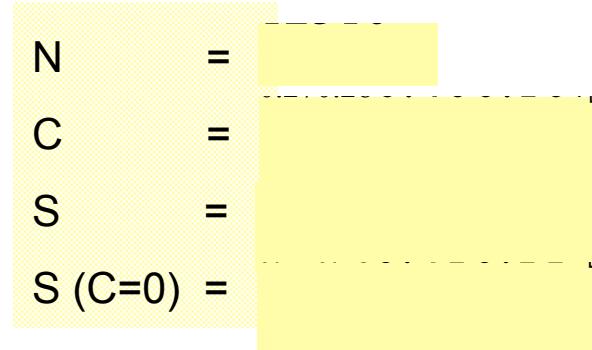
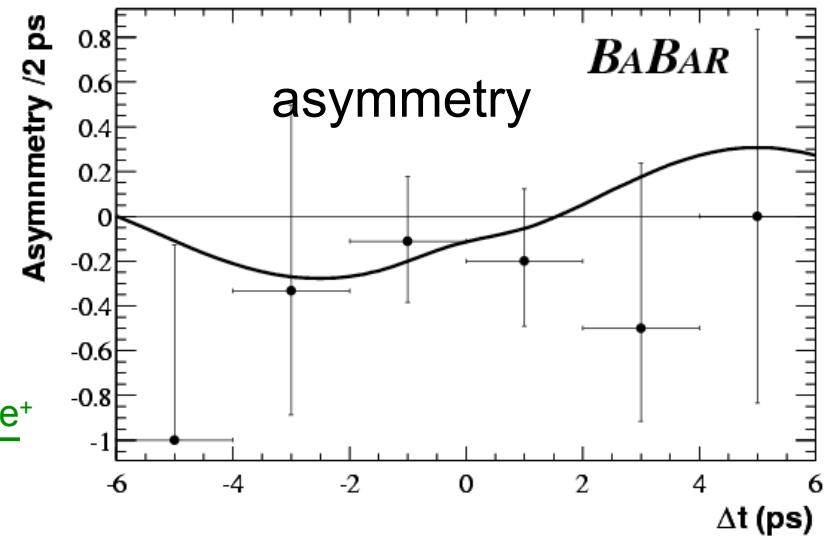
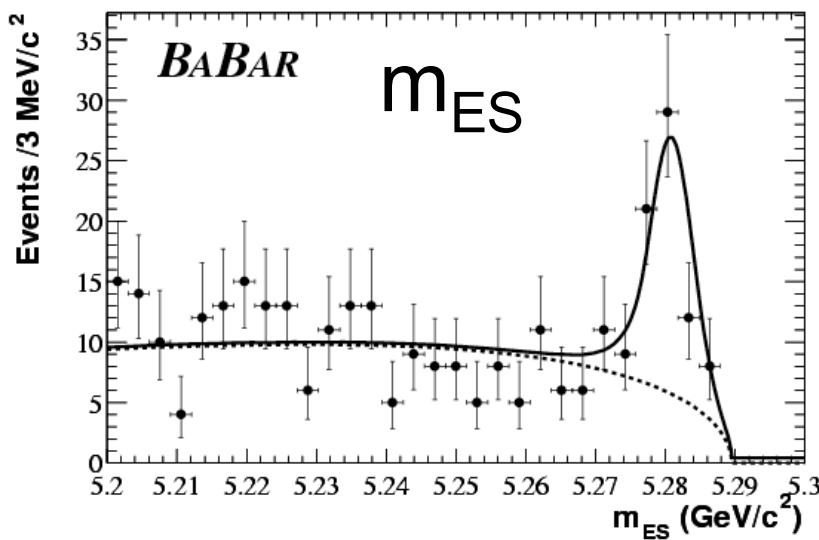
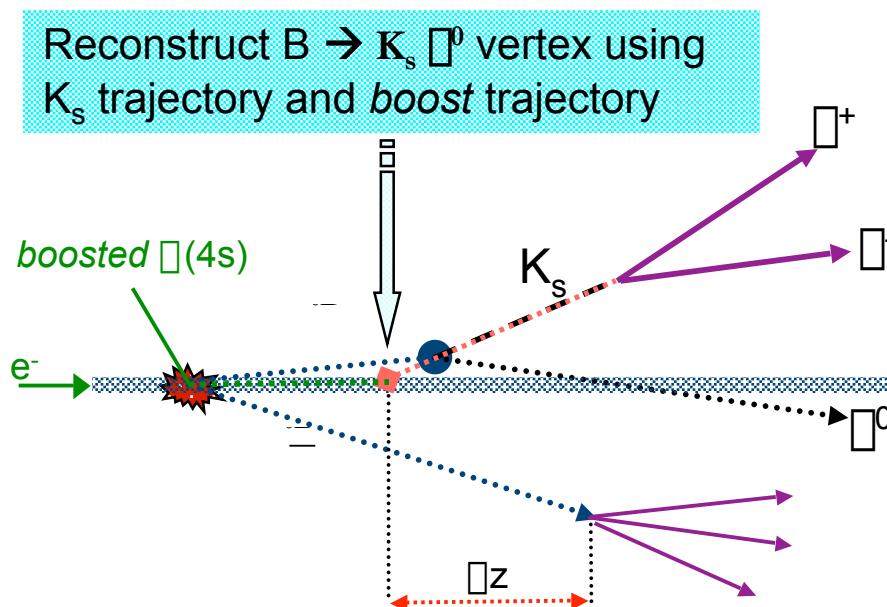
If A is fixed to zero, $S = -0.99 \pm 0.50$

Belle 2003: CP Asymmetry in $B \rightarrow K_S$



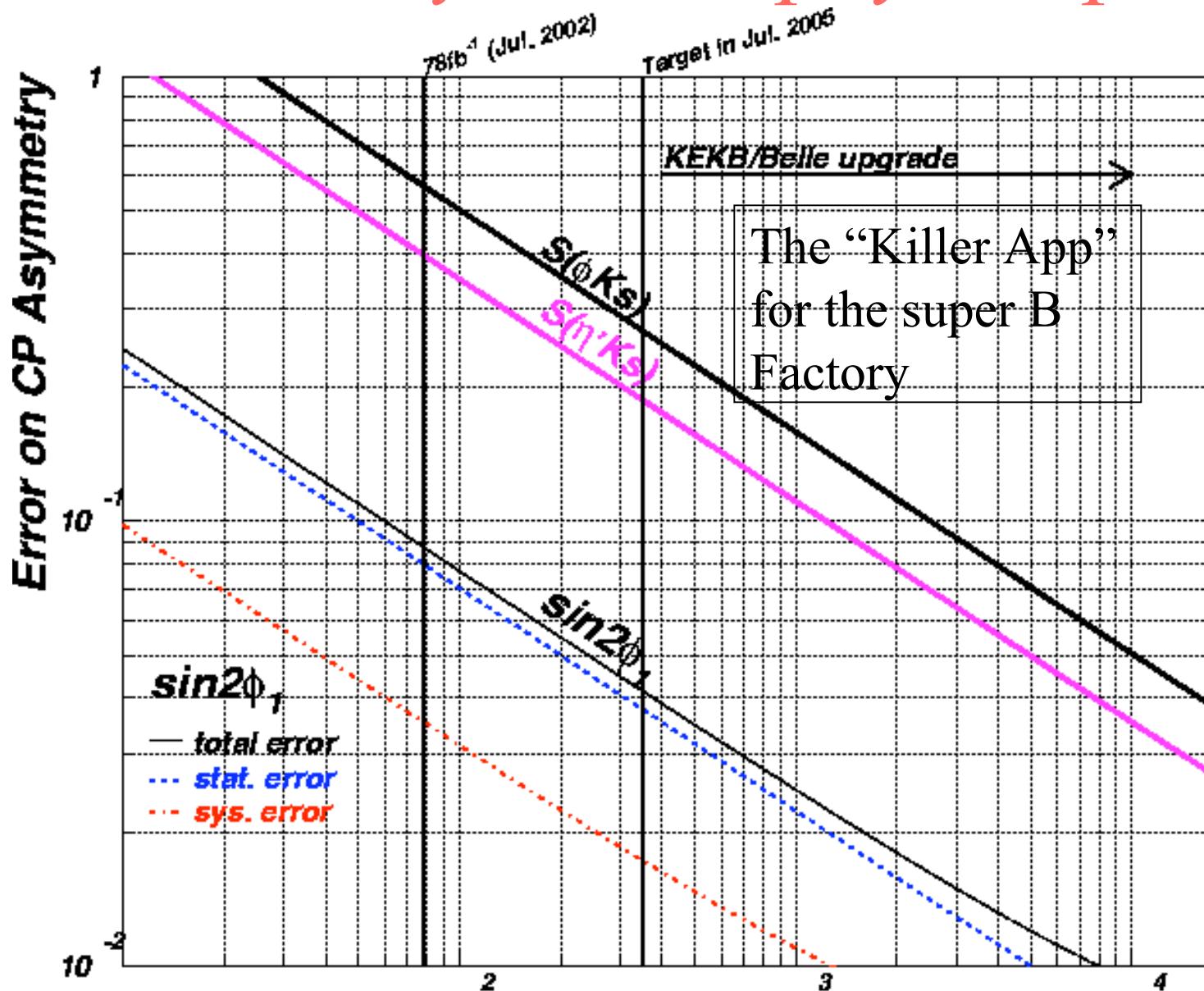
Feldman-Cousins treatment including systematic from CP in the background finds the K_S value ruled out at 99.95% CL or 3.5 σ

BaBar: CPV with $B^0 \rightarrow K_s \bar{\ell}^0$ [$b \rightarrow s d \bar{d}$]



In the absence of
New Physics, $S = \sin(2\beta_1)$
 $= 0.731 \pm 0.056$

Sensitivity to new physics phases



Conclusions

*New precise measurement of $\sin(2\beta)$ from Belle
in $b \rightarrow c \bar{c} s$ modes. Large CPV measured in these
decays by BaBar and Belle consistent with the
CKM framework.*

*Measurements of CPV in $b \rightarrow c \bar{c} d$
modes not yet precise enough to detect
whether there is penguin pollution.*

CPV in $b \rightarrow s$ penguins: a surprise in $B \rightarrow K_S$.
Belle finds a 3.5 σ deviation from the SM while
BaBar moves closer towards the SM.

Backup Slides

Belle 2003: Table of sin2_{_1} values for b→c cbar s CP eigenstates.

TABLE III: The numbers of candidate events, N_{ev} , and values of $\sin 2\phi_1$ for various subsamples (statistical errors only).

Sample	N_{ev}	$\sin 2\phi_1$
$J/\psi K_S^0(\pi^+\pi^-)$	1997	0.67 ± 0.08
$J/\psi K_S^0(\pi^0\pi^0)$	288	0.72 ± 0.20
$\psi(2S)K_S^0$	308	0.89 ± 0.20
$\chi_{c1}K_S^0$	101	1.54 ± 0.49
$\eta_c K_S^0$	217	1.32 ± 0.29
All with $\xi_f = -1$	2911	0.73 ± 0.06
$J/\psi K_L^0$	2332	0.80 ± 0.13
$J/\psi K^{*0}(K_S^0\pi^0)$	174	0.10 ± 0.45
$f_{\text{tag}} = B^0$ ($q = +1$)	2717	0.72 ± 0.09
$f_{\text{tag}} = \overline{B}^0$ ($q = -1$)	2700	0.74 ± 0.08
$0 < r \leq 0.5$	2985	0.95 ± 0.26
$0.5 < r \leq 0.75$	1224	0.68 ± 0.11
$0.75 < r \leq 1$	1208	0.74 ± 0.07
data set I (78 fb^{-1})	3013	0.73 ± 0.07
data set II (62 fb^{-1})	2404	0.74 ± 0.09
All	5417	0.733 ± 0.057

Belle 2003: Table of yields for
 $b \rightarrow c\bar{c} s$ CP eigenstates.

Mode	ξ_f	N_{ev}	Purity
$J/\psi K_S^0$	-1	1997	0.976 ± 0.001
$J/\psi K_S^0(\pi^0\pi^0)$	-1	288	0.82 ± 0.02
$\psi(2S)K_S^0$	-1	145	0.93 ± 0.01
$\psi(2S)(J/\psi\pi^+\pi^-)K_S^0$	-1	163	0.88 ± 0.01
$\chi_{c1}(J/\psi\gamma)K_S^0$	-1	101	0.92 ± 0.01
$\eta_c(K_S^0 K^- \pi^+) K_S^0$	-1	123	0.72 ± 0.03
$\eta_c(K^+ K^- \pi^0) K_S^0$	-1	74	0.70 ± 0.04
$\eta_c(p\bar{p})K_S^0$	-1	20	0.91 ± 0.02
All with $\xi_f = -1$	-1	2911	0.933 ± 0.002
$J/\psi K^{*0}(K_S^0\pi^0)$	+1(81%)	174	0.93 ± 0.01
$J/\psi K_L^0$	+1	2332	0.60 ± 0.03

BELLE-CONF-0353

Belle 2003: Systematic Uncertainties for $b \rightarrow s$ CPV modes

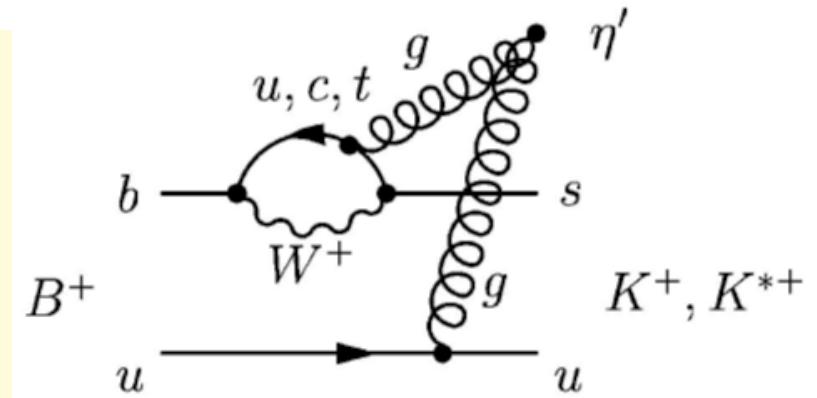
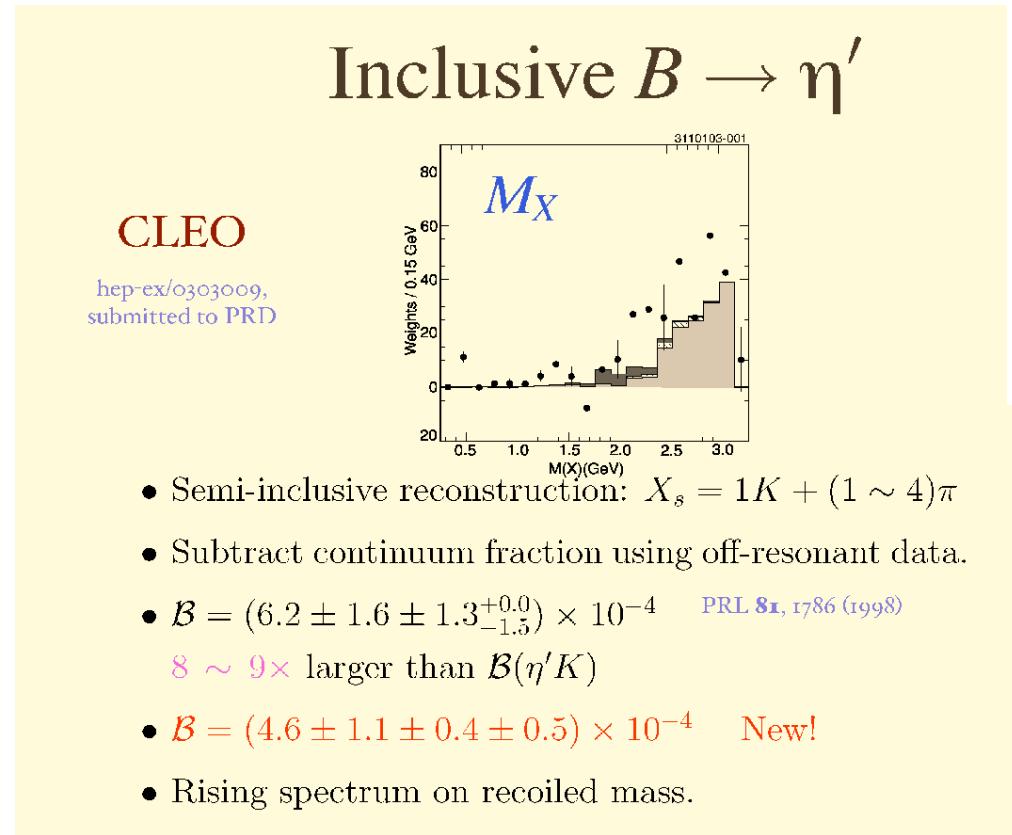
	\bar{K}^*_S		\bar{K}'^*_S		KKK	
	S	A	S	A	S	A
Wtag fractions	± 0.018	± 0.007	± 0.005	± 0.006	± 0.005	± 0.007
Physics parameters	± 0.033	± 0.002	± 0.006	± 0.002	± 0.003	± 0.003
Vertexing	± 0.022	± 0.046	± 0.016	± 0.027	± 0.044	± 0.024
Background fraction	± 0.053	± 0.035	± 0.045	± 0.026	± 0.029	± 0.036
Background $\bar{t}t$	± 0.015	± 0.008	± 0.003	± 0.003	± 0.010	± 0.006
Resolution function	± 0.013	± 0.005	± 0.004	± 0.003	± 0.007	± 0.004
KKKs + $f_0 K_S$ bkg.	$+0.001 \pm 0.039$		-0.084			
Sum			$+0.09 \pm 0.07 \pm 0.05 \pm 0.04 \pm 0.05$			
± 0.04			-0.11			

Systematics are small and well understood from $b \rightarrow c$ $c\bar{b}$ s studies

Belle vs BaBar

- Belle: $\sin^2_{\text{eff}}(B \rightarrow K_S) = 0.96 \pm 0.50^{+0.09}_{-0.11}$
- BaBar: $\sin^2_{\text{eff}}(B \rightarrow K_S) = +0.45 \pm 0.43 \pm 0.07$
- There is a 2.1 σ discrepancy between the exps.
- Average $= -0.15 \pm 0.33$ (Still 2.7 σ from the SM)

Mystery of Large Inclusive $B \rightarrow _ X_s$



“gluon anomaly”

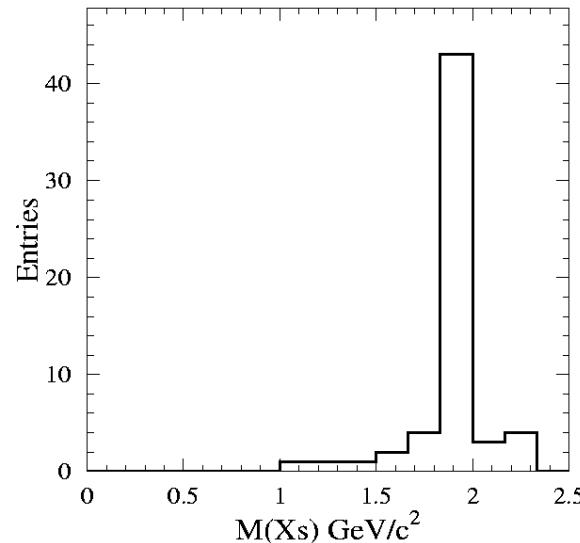
c.f. Babar: hep-ex/0109034: $B \rightarrow _ X_s = (6.8^{+0.7}_{-1.0} \pm 1.0 \pm 0.5) \times 10^{-4}$

BaBar: $B \rightarrow X_s$ inclusive

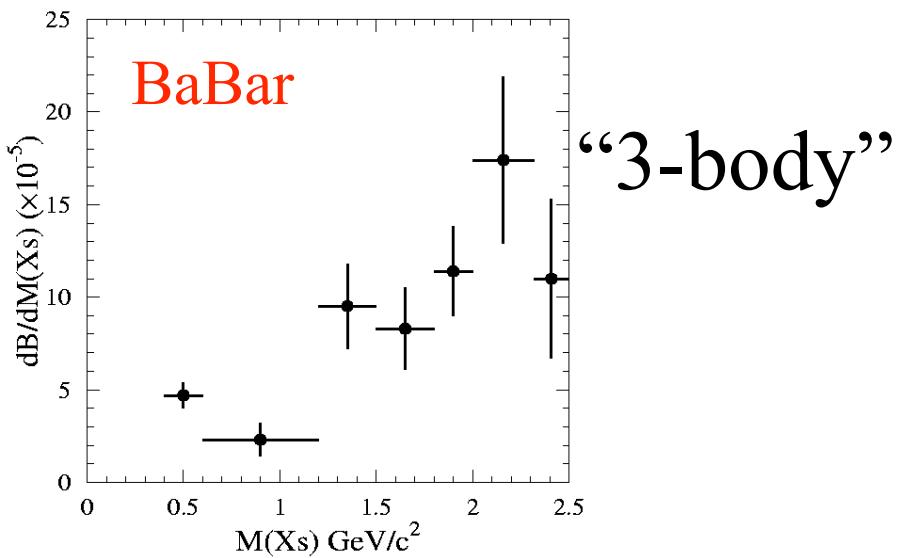
*QCD anomaly: e.g D. Atwood
and A. Soni, W.S. Hou and
Tseng*



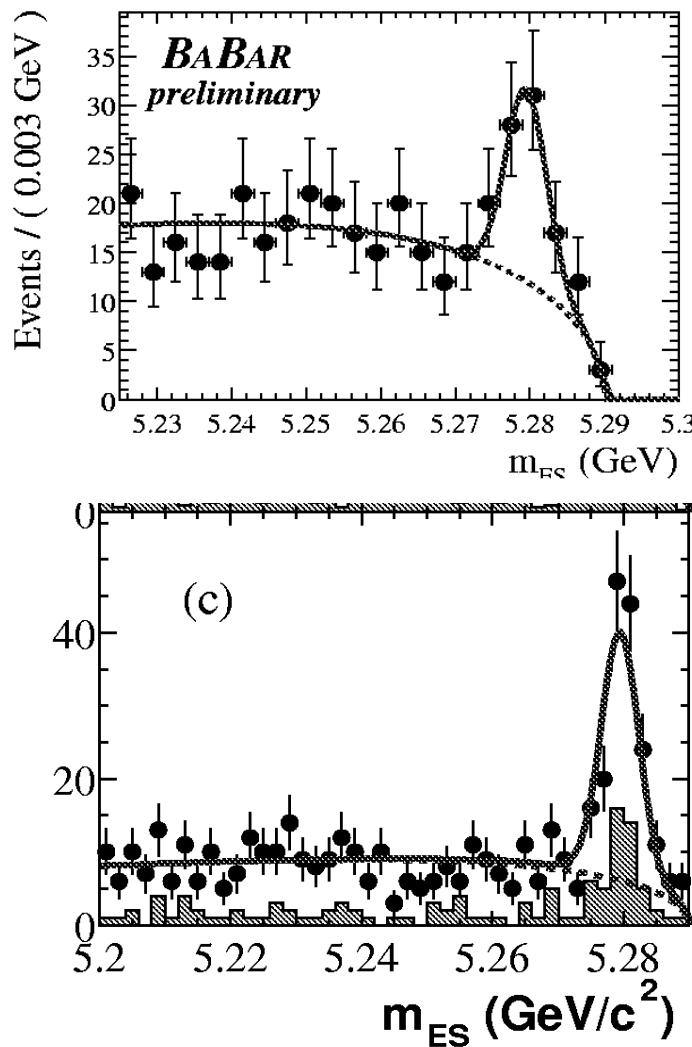
Figure 3: $M(X_s)$ spectrum predicted from simulation of $\bar{B}^0 \rightarrow \eta' D^0$ decays



*Kagan+Petrov: CLEO $\chi_{c1}(1S)$
data show that the χ_{c1} gg form
factor falls off too fast. [c.f.
Ali+Parkhomenko, E. Kou]*



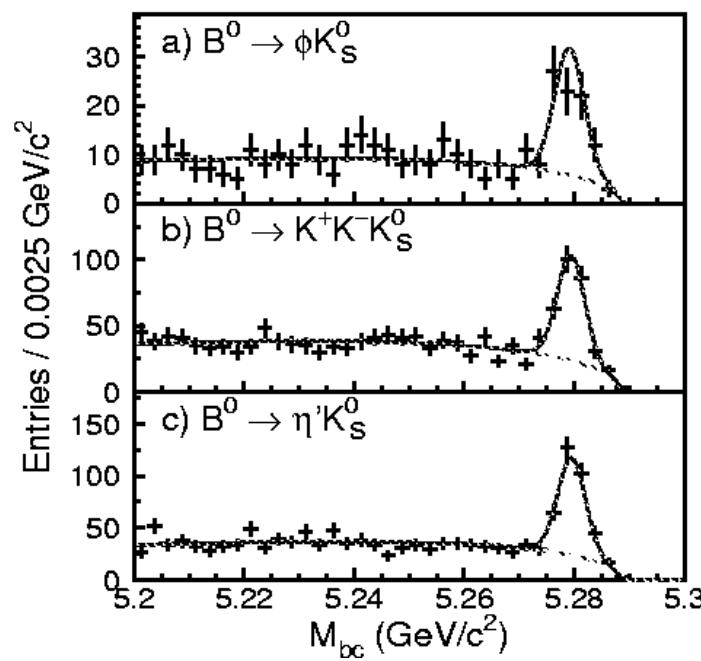
Signals for BaBar $b \rightarrow s$



Signals for Belle $b \rightarrow s$ CPV analysis.

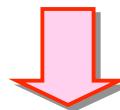
TABLE I: The numbers of reconstructed $B^0 \rightarrow f_{CP}$ candidates used for \mathcal{S} and \mathcal{A} determination, N_{ev} , and the estimated signal purity in the $\Delta E - M_{bc}$ signal region for each f_{CP} mode.

Mode	ξ_f	N_{ev}	Purity
ϕK_S^0	-1	106	0.64 ± 0.10
$K^+ K^- K_S^0$	+1(100%)	361	0.55 ± 0.05
$\eta' K_S^0$	-1	421	0.58 ± 0.05

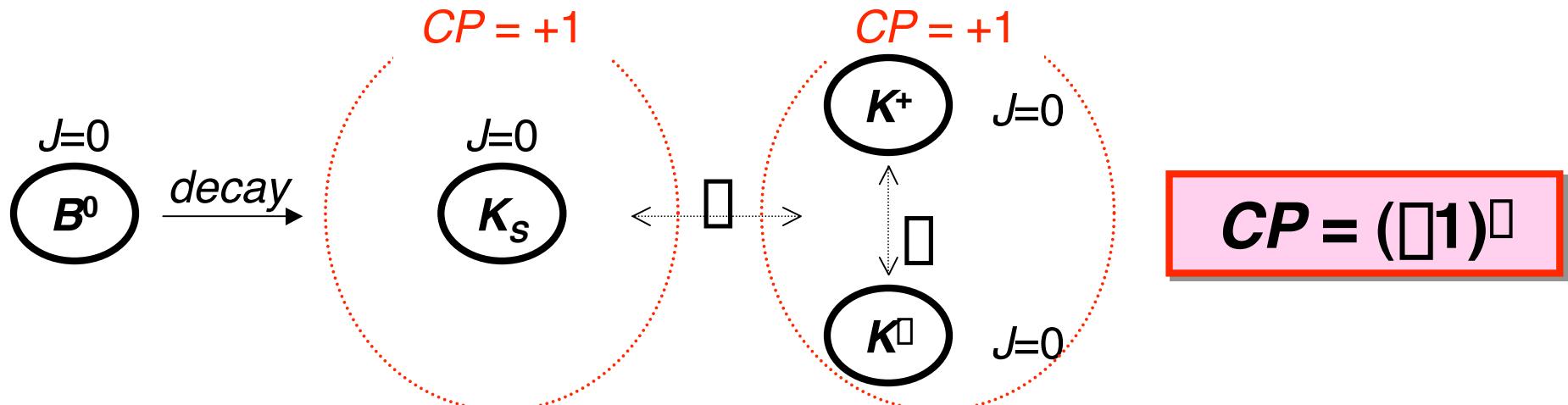


$B^0 \rightarrow K^+ K^- K_S$: $CP = \pm 1$ Mixture

Since $B^0 \rightarrow K^+ K^- K_S$ is 3-body decay,
the final state is a mixture of $CP = \pm 1$.
How can we determine the admixture ?

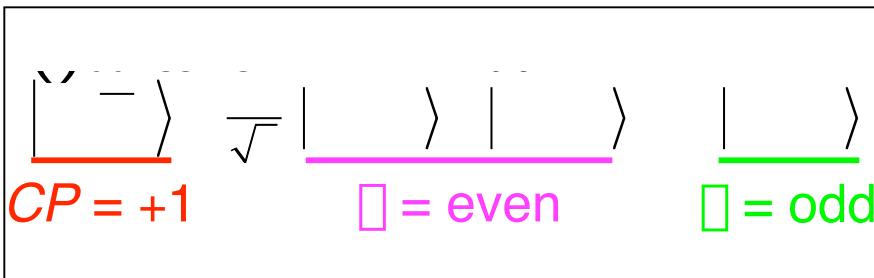


$CP = \pm 1$ fraction is equal to that of $\square = \text{even/odd}$



$B^0 \rightarrow K^+ K^- K_S$: $CP = \pm 1$ Content

\square -even fraction in $|K^0 K^0\rangle$ can be determined by $|K_S K_S\rangle$ system



Add K^+ to above kets

$$|K^+ K^- K_S\rangle = \sqrt{\frac{1}{2}} |K^+ K^- K_S\rangle + \sqrt{\frac{1}{2}} |K^+ K^- K_S\rangle$$

Using isospin symmetry

$$\begin{aligned} BF(B^+ \rightarrow K^+ K^0 K^0) &= BF(B^0 \rightarrow K^0 K^+ K^\square) \bar{\square}(B^+) / \bar{\square}(B^0) \\ &= \frac{1}{2} BF(B^0 \rightarrow K^0 K^+ K^\square) \bar{\square}(B^+) / \bar{\square}(B^0) \end{aligned}$$

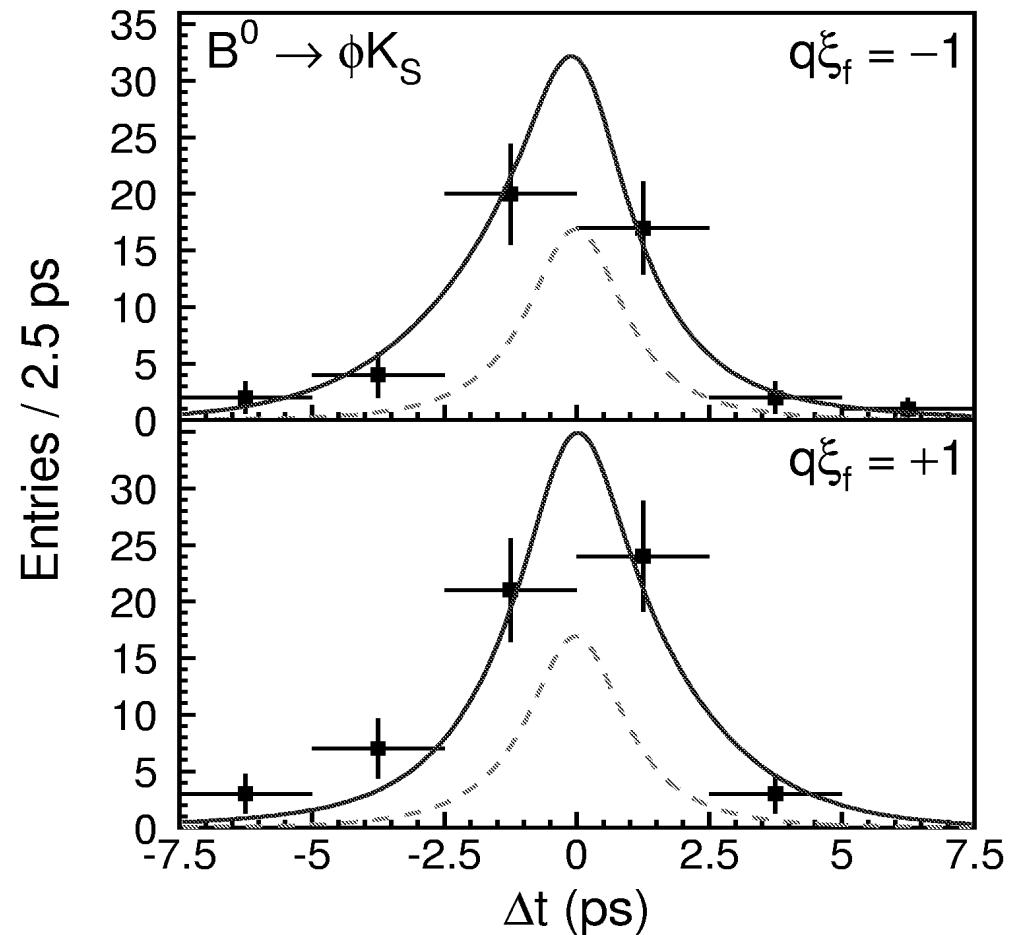
$$a^2 = \frac{2BF(B^+ \rightarrow K^+ K_S K_S) \bar{\square}(B^0)}{BF(B^0 \rightarrow K^0 K^+ K^\square) \bar{\square}(B^+)}$$

$$= \frac{BF(B^+ \rightarrow K^+ K_S K_S) \bar{\square}(B^0)}{BF(B^0 \rightarrow K_S K^+ K^\square) \bar{\square}(B^+)}$$

$$= 1.026 \pm 0.15(\text{stat}) \pm 0.05(\text{sys})$$

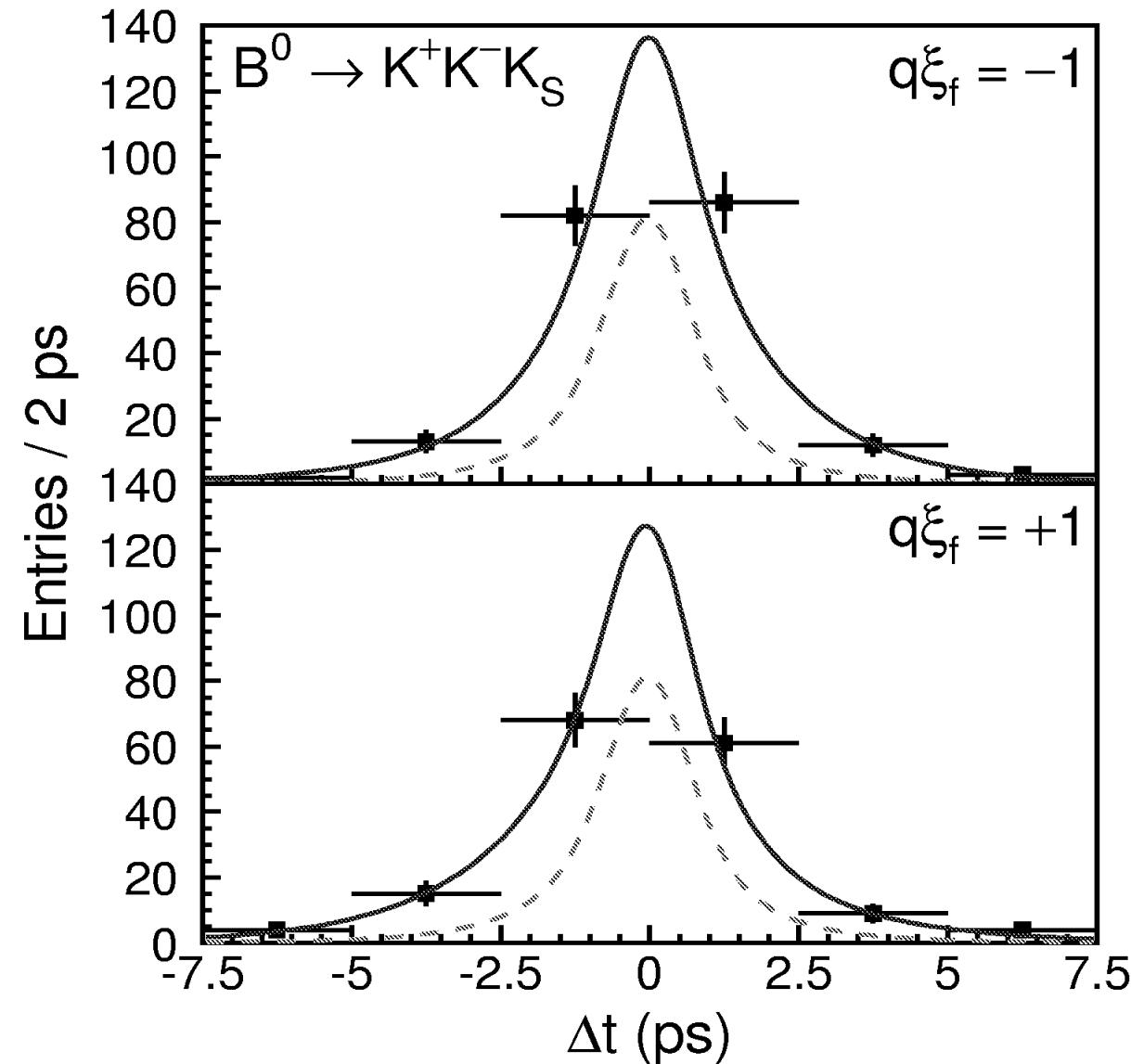
100	⁺⁰ ₋₁₅	% CP Even
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Belle 2003: CP Asymmetry in $B \rightarrow K_S$

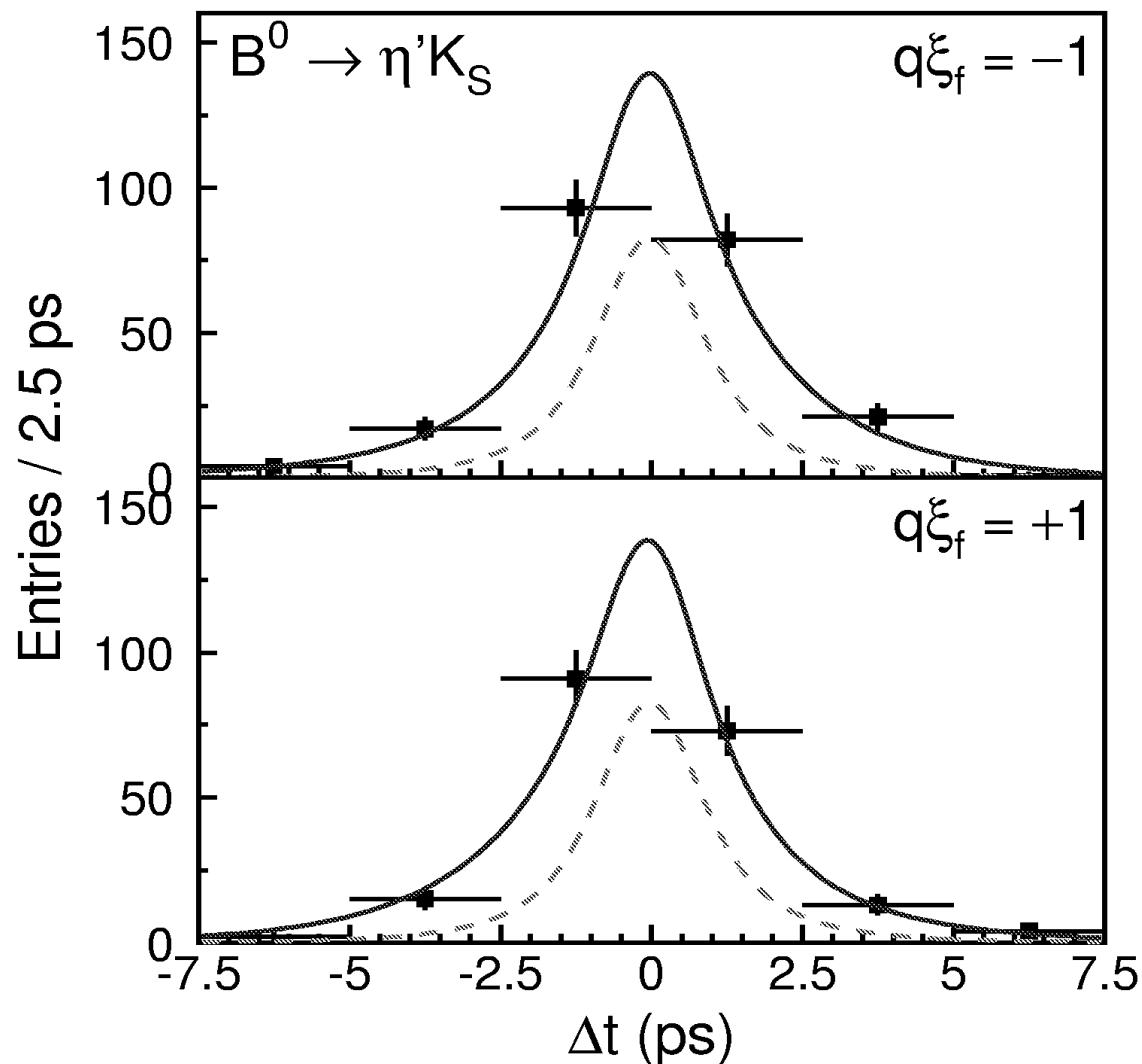


All r bins

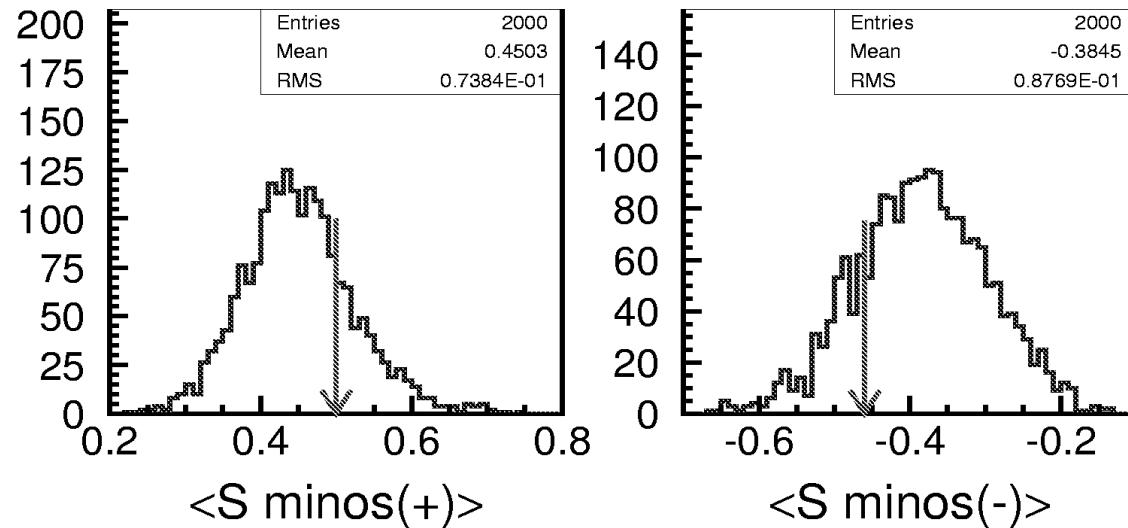
Belle 2003: CP Asymmetry in $B \rightarrow K^+ K^- K_S$



Belle 2003: CP Asymmetry in $B \rightarrow \eta' K_S$



Belle 2003: Toy MC studies of the errors for $B \rightarrow K_S$



Errors are slightly larger than expected.

Belle 2003: CPV in $b \rightarrow s$ modes (additional details)

TABLE II: Results of the fits to the Δt distributions. The first errors are statistical and the second errors are systematic. The third error for the $K^+ K^- K_S^0$ mode arises from the uncertainty in the fraction of the CP -odd component.

Mode	$-\xi_f \mathcal{S}$ ($= \sin 2\phi_1$ in the SM)	\mathcal{A} ($= 0$ in the SM)
ϕK_S^0	$-0.96 \pm 0.50^{+0.09}_{-0.11}$	$-0.15 \pm 0.29 \pm 0.07$
$K^+ K^- K_S^0$	$+0.51 \pm 0.26 \pm 0.05^{+0.18}_{-0.00}$	$-0.17 \pm 0.16 \pm 0.04$
$\eta' K_S^0$	$+0.43 \pm 0.27 \pm 0.05$	$-0.01 \pm 0.16 \pm 0.04$

Belle 2003: CPV in $b \rightarrow s$ modes (additional details)

TABLE I: The numbers of reconstructed $B^0 \rightarrow f_{CP}$ candidates used for \mathcal{S} and \mathcal{A} determination, N_{ev} , and the estimated signal purity in the ΔE - M_{bc} signal region for each f_{CP} mode.

Mode	ξ_f	N_{ev}	Purity
ϕK_S^0	-1	106	0.64 ± 0.10
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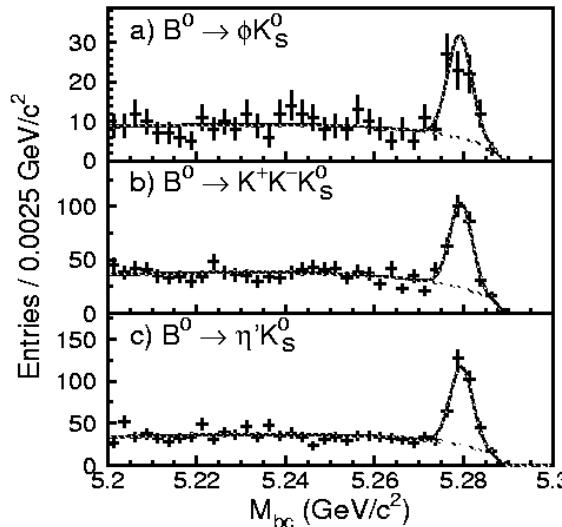
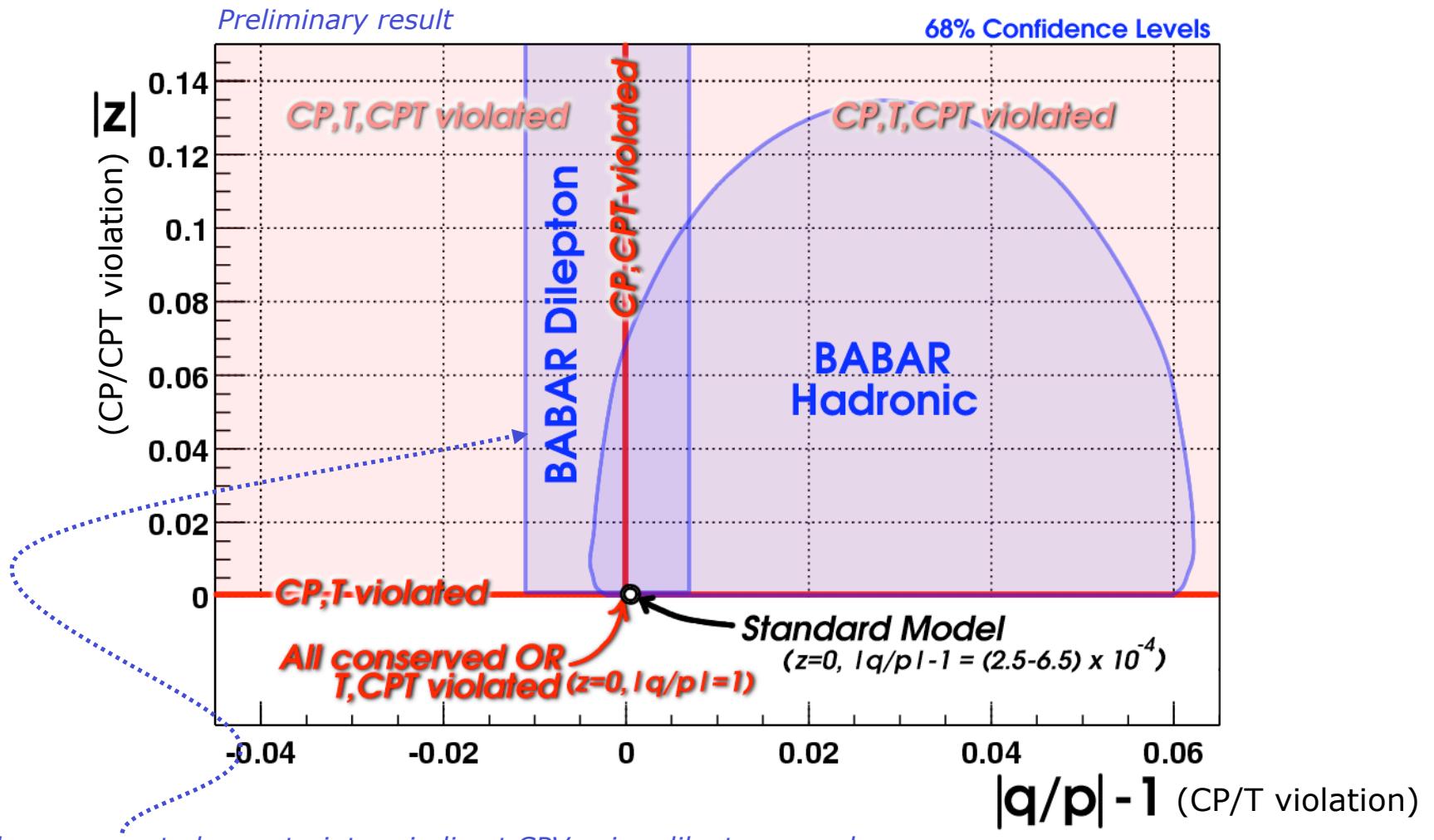


FIG. 1: The beam-energy constrained mass distributions for (a) $B^0 \rightarrow \phi K_S^0$, (b) $B^0 \rightarrow K^+ K^- K_S^0$, and (c) $B^0 \rightarrow \eta' K_S^0$ within the ΔE signal region. Solid curves show the fit to signal plus background distributions, and dotted curves show the background contributions. The background for $B^0 \rightarrow \eta' K_S^0$ decay includes an MC-estimated $B\bar{B}$ background component.

Limits on \bar{Z} and search for CP, T, CPT violation in mixing

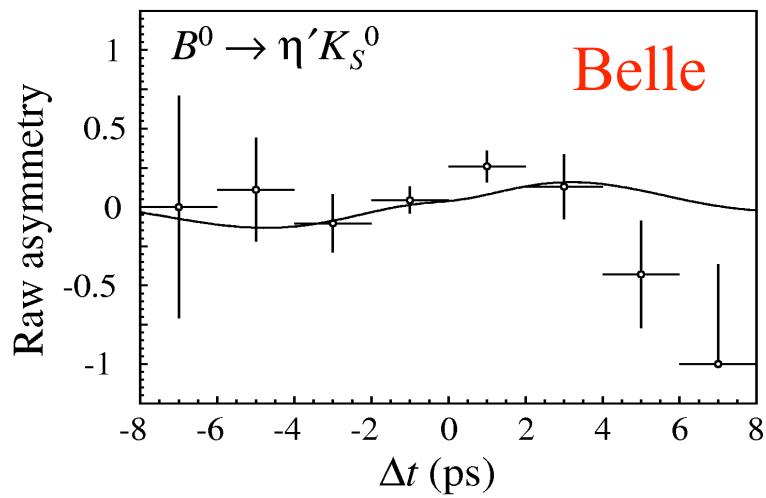
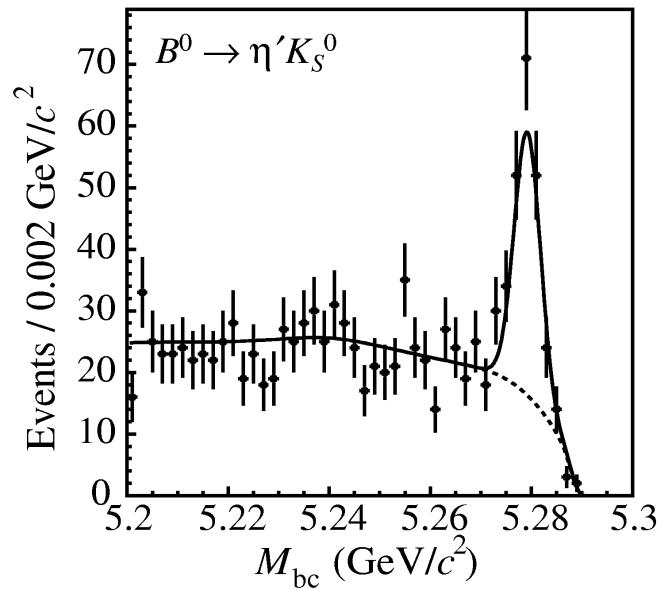


Also represented: constraint on indirect CPV using dilepton sample

$$a_T(\Delta t) \equiv \frac{\mathcal{N}(\ell^+\ell^+) - \mathcal{N}(\ell^-\ell^-)}{\mathcal{N}(\ell^+\ell^+) + \mathcal{N}(\ell^-\ell^-)} \approx \frac{1 - |q/p|^4}{1 + |q/p|^4} \quad \rightarrow \quad a_T = (0.5 \pm 1.2 \pm 1.4)\%$$

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(2002) 201802

$$N(\eta' K_S) = 146 \pm 12$$



*Search for New Physics
in the $B \rightarrow \eta' K_S$ penguin
decay.*

Belle: $S_{\eta' K_S} = 0.71 \pm 0.37$
 $+0.05$
 -0.06

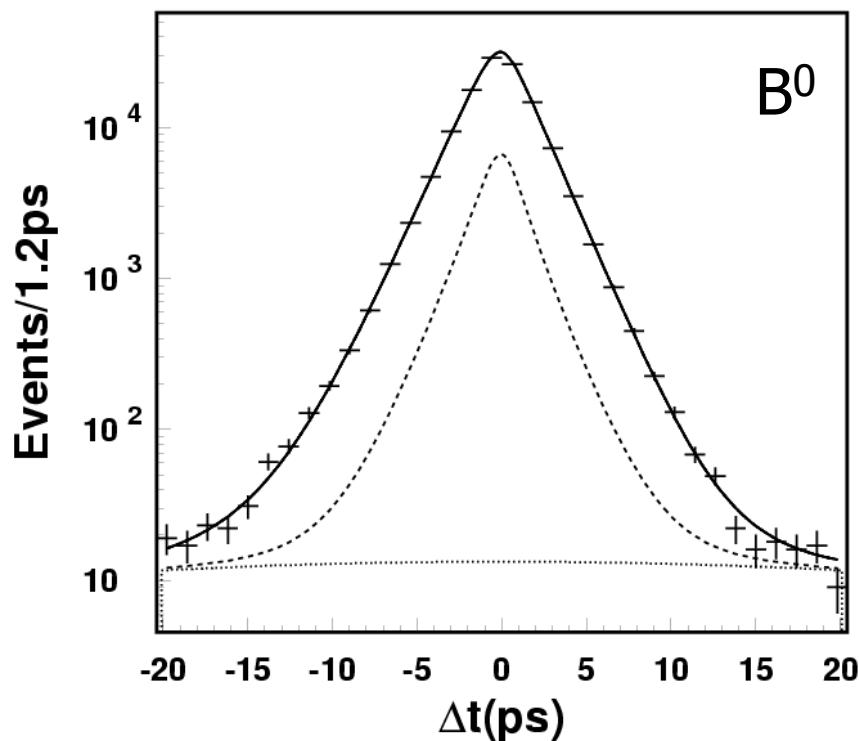
Babar: $S_{\eta' K_S} = 0.02 \pm 0.34 \pm 0.03$

In the absence of New Physics, $S_{\eta' K_S} = \sin(2\alpha_1)$
 (a.k.a. $\sin(\bar{2}\alpha)$)

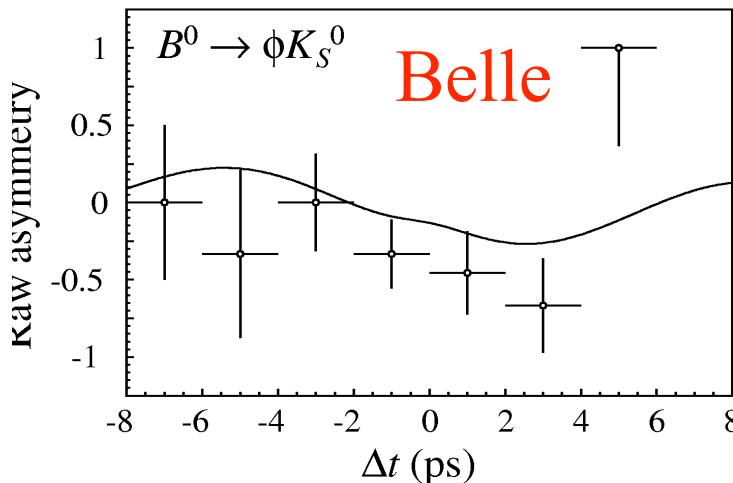
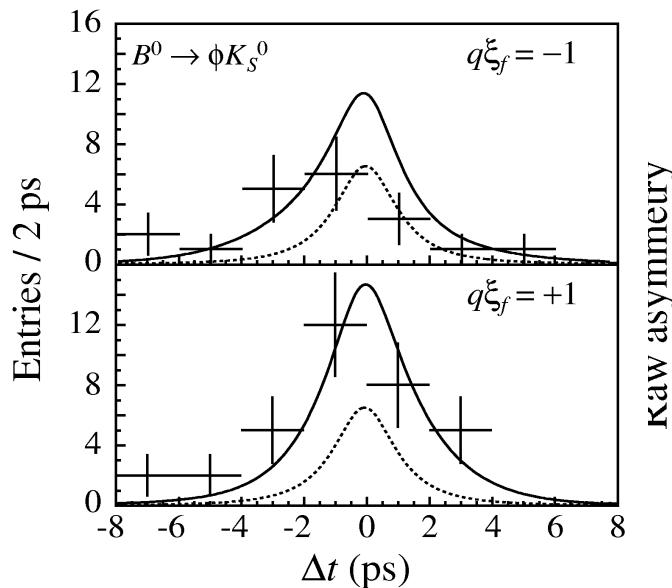
Current WA: $\sin(2\alpha_1) = 0.734 \pm 0.055$

Control samples:
Resolution Parameters and B^0 and B^\pm Lifetime

$\tau_{B^0} = 1.533 \pm 0.008(\text{stat}) \text{ ps}$
(PDG2003 1.537 0.015)
 $\tau_{B^+} = 1.634 \pm 0.011(\text{stat}) \text{ ps}$
(PDG2003 1.671 0.018)



2002 Status of new phases in $b \rightarrow s$ penguins



(hep-ph/0209290), J-P Lee,
K. Y. Lee; (hep-ph/0208226) B. Dutta, C.S. Kim and S. Oh; (hep-ph/0208091), M. Raidal; (hep-ph/0208087), M. Ciuchini, L. Silvestrini; (hep-ph/0208016), A. Datta; (hep-ph/0208005), H. Murayama; (hep-ph/0207356), G. Hiller; (hep-ph/0207070), M-B. Causse; (hep-ph/0208080) Y. Nir

Belle: $\sin 2_{-1\text{eff}} = -0.73 \pm 0.64 \pm 0.22$

Babar: $\sin 2_{-1\text{eff}} = -0.18 \pm 0.51 \pm 0.09$

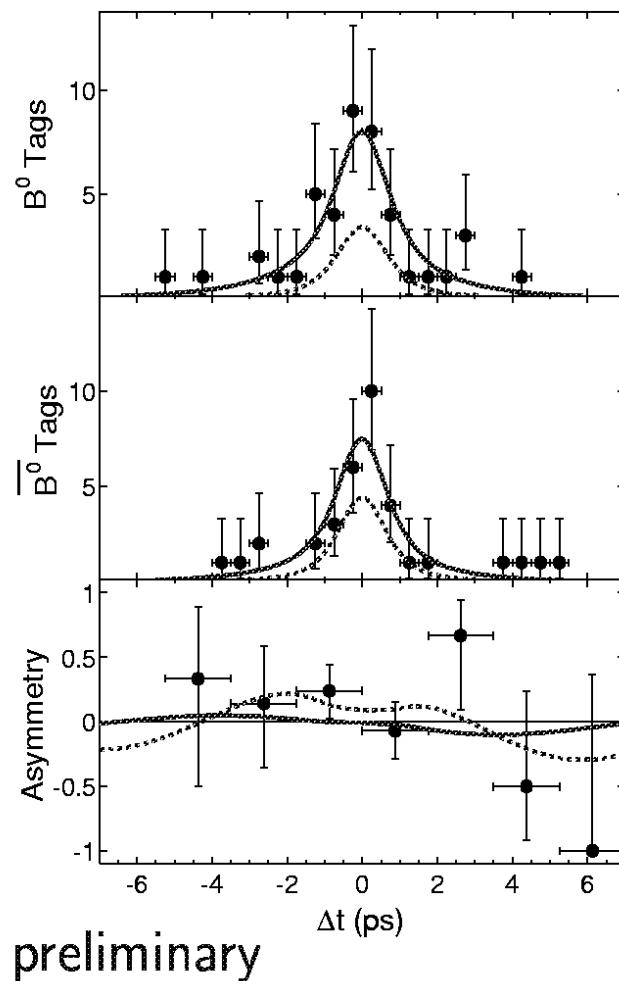
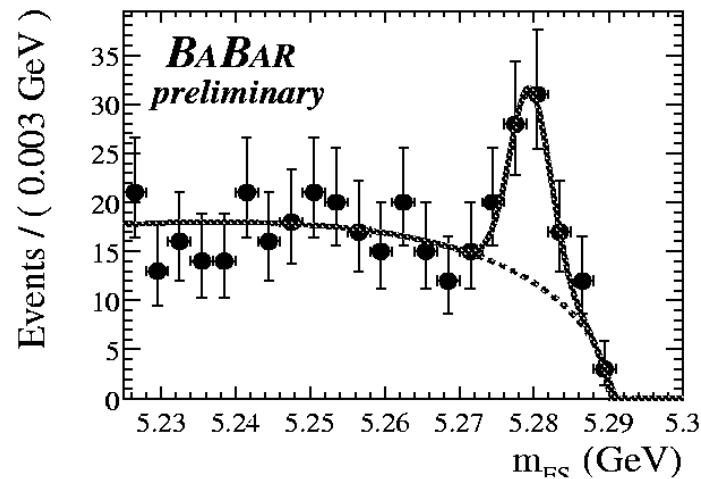
2.7 off

WA: $\sin 2_{-1\text{eff}} (-K_S) = -0.38 \pm 0.41$



BaBar 2002: $B \rightarrow K_S$

BaBar 2002: 81 fb^{-1}



Babar 2002: $\sin^2 \theta_{1\text{eff}} (_ K_S) = -0.18 \pm 0.51 \pm 0.09$